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Construction Engineering Research Laboratory

US Army Corps of Engineers® Engineer Research and Development Center

US Army Corps of Engineers (USACE) Renewable Energy Study

Feasibility of Renewable Energy Technology at the Afghanistan National Security University

A Site-Specific Study Focused on Potential Renewable Energy Technologies in Northwest Kabul, Afghanistan

William T. Brown, John Vavrin, Tarek Abdallah, Jarod Delhotal, Roch Ducey, Franklin H. Holcomb, Nicholas A. Reisweber, Patrick J. Sioson, Chang W. Sohn, William J. Stein, Seth W. Broadfoot, Brian Kamisato, Jerry Christensen, Charles Allen, John Etzel, Jeff Hurt, Daniel Patla, Joseph Van Winkle, Ravi Seam, Suresh Kikkeri, Tiffany Ferguson, and Michael Valerio

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Construction Engineering Research Laboratory (CERL)
US Army Engineer Research and Development Center
2902 Newmark Dr.
Champaign, IL 61822-1076

Seth W. Broadfoot

Geotechnical and Structures Laboratory (GSL)
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Brian Kamisato

US Army Engineer Division, Northwestern
P.O. Box 2870
Portland, OR 97208-2870

Jerry Christensen, Charles Allen, John Etzel, Jeff Hurt, Daniel Patla, and Joseph Van Winkle

US Army Engineer District, Portland
P.O. Box 2946
Portland, OR 97208-2946

Ravi Seam, Suresh Kikkeri, Tiffany Ferguson, and Michael Valerio

US Army Corps of Engineers
Transatlantic Division
255 Fort Collier Road
Winchester, VA 22603-5776

Nicholas A. Reisweber and Patrick J. Sioson

US Military Academy
West Point, NY 10996

Final Report

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Abstract: This work conducted a site-specific feasibility study to assess the potential use of renewable energy to reduce or replace planned fossil-fueled generators at the Afghanistan National Security University (ANSU) and its supporting facilities located in Qargha, Kabul, Afghanistan. On completion of all phases of construction, ANSU will consume approximately $45M of diesel fuel annually for power production. The Afghanistan Engineer District – North commissioned the US Army Corps of Engineers, Engineering Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) to investigate renewable energy solutions to reduce that annual fuel cost. The team investigated the following technologies: solar photovoltaic (ground-mounted and building-integrated), solar domestic hot water (DHW), wind, geothermal, geo-thermal (ground-source) heat pumps, waste-to energy (including biomass), solar air collector, solar air ventilation, fuel cells, and hydroelectric power. Qualitative facility demand and energy reduction measures were also included. These energy conservation measures can be used as part of the planning and design phases of construction. On review of all potential options, it was determined that seven renewable energy systems were viable, and eight renewable energy technologies were not viable.

Executive Summary

The new Afghanistan National Security University (ANSU) campus, located in Qargha, Afghanistan approximately 8 miles west from Kabul, Afghanistan, will be considered the "crown jewel of military education" for the Afghan National Army (ANA). When complete, it will have over 100 academic, administration, and support buildings sustaining over 8000 personnel and their equipment. With no reliable electric grid support, the ANSU campus will need to support a peak electrical demand of approximately 16 megawatt (MW) via the use of a 20-MW total diesel generator capacity, which will consume a projected annual diesel fuel consumption cost of around $45 million/yr.

To reduce ANSU's energy and operational costs, while supporting the goal of energy security and sustainability, the North Atlantic Treaty Organization (NATO) Training Mission – Afghanistan (NTM-A) / Combined Security Transition Command – Afghanistan (CSTC-A) and US Forces – Afghanistan (USFOR-A) Joint Program Integration Office (JPIO) contacted the US Army Corps of Engineers (USACE) to request an assessment of the feasibility of using renewable energy systems to reduce the fuel demand.

The use of renewable energy systems will help the ANA attain a more efficient and sustainable installation while maintaining mission capability and readiness. Renewable energy systems will reduce the amount of fuel that must be transported to the complex along the single two-lane access road leading up to the ANSU complex. This will, in turn, reduce the number of convoys needed to transport fuel, alleviate the dangers to soldiers and fuel delivery personnel who man they convoys, and lessen the estimated $45 million annual cost to fuel diesel generators. Resources and personnel currently used to support base operations may be more effectively focused on the mission. Also, reduced fuel consumption will also cut exhaust fumes and carbon emissions from the site, and improve local air quality.

The goal of this study was to:

1. Assess all renewable energy options commercially available to the ANSU complex
2. Determine the feasibility of each option for the site

3. Calculate projected fuel savings and simple payback for each option
4. Project the long-term consequences for each renewable energy technology
5. Determine overall best practices for ANSU to reduce building load demand and energy consumption.

While this study documented the rationale for choosing “proven” and commercially-available renewable energy technologies for purposes of the ANSU feasibility analysis, it also provided documentation on “unproven” technologies (i.e., technologies that do not have full-scale operational data and are not commercially available).A follow-on effort could provide technical input to a design-build contract for any of the recommended alternatives, and/or provide Contracting Officer Technical Representative (COTR) support for any follow-on contracting activities.

The team of experts from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), the USACE Hydroelectric Design Center (HDC), Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL), and cadets from the US Military Academy investigated the feasibility of these renewable energy technologies:

- solar photovoltaic (ground-mounted and building-integrated)
- solar domestic hot water (DHW)
- wind
- geothermal
- geothermal (ground-source) heat pumps (GSHPs)
- waste-to energy (WTE)
- biomass
- solar air collector
- solar air ventilation
- fuel cells
- hydroelectric power.

For each technology, the study also provided an assessment of operations and maintenance (O&M) complexities and long-term considerations to inform NTM-A / CSTC-A senior leaders of probable future issues that may be associated with the implementation of these technologies.

The ANA receives/purchases diesel fuel at a cost of $1.16/L, or about $4.40/gal. (This value was verified by the CSTC-A Combined-Joint Logis-

tics Officer [CJ4]). The investigation team used this cost as the “fully burdened cost of fuel” for the study, but also analyzed economics using $10/gal and $20/gal as part of a sensitivity analysis.

Note that the command also expressed interest in the use of hydropower, provided by the close by Qargha Dam. This analysis concluded that hydropower would not be a viable source of power to reduce the ANSU’s dependence on power generated from fossil fuels. Good quality data and reasonable assumptions indicate that the maximum possible power available from the site would be about 90 kW. Of the three scenarios analyzed, the most optimistic minimum payback period for the capitalized cost of construction, based on the current fully burdened fuel cost, would be 13.5 yrs. To improve the reliability of the data and assumptions, it would be advisable to check the water flow rate and total capacity of the dam to be able to support a 90-kW system.

While the use of passive solar design (covered in the energy reduction measures) and energy conservations measures were not quantitatively analyzed, these design techniques are typically the most cost-effective in this type climate. The climate at the ANSU site is very close to that in Flagstaff, AZ in latitude, elevation, and solar resource. Therefore, that location was used as a reference for much of this analysis.

Table ES1 summarizes the economic results of the renewable study, including capital costs, O&M costs, simple payback, savings-to-investment ratio (SIR), and annual fuel savings.

Table ES1. Renewable energy technology economic summary.

Feasibility	Technology	Size	Land Use	Capital Cost Afghanistan	Annual O&M Cost– Afghanistan	Simple Payback (yrs)	Years to SIR > 1	Annual Fuel Savings (gals)	% Diesel Fuel Reduction
Feasible	Solar Air Collector	5,050 m^2	______	$120,000	$3,000	5.7	10	5,000	0.05%
	Solar Wall (Auditorium)	2,600 m^2	______	$721,000	$6,000	8.7	10	19,000	0.2%
	Biodiesel	200,000 gpy (gal/yr)	2000 acres	$900,000	$180,000	2	5	105,000	1.0%
	Waste-to-Energy (WTE) Incinerator	0.4 MW (16 tons/day)	0.5 acre	$3 million	$430,000	4.5	10	152,000	1.5%
	Wind	1000 kW	<1 acre each	$6 million	$75,000	8.2	15	167,000	1.6%
	Solar DHW Heater	250,000 L/d	2500 m^2	$8 million	$15,000	11	15	165,000	1.6%
	Solar Photovoltaic (PV) Ground-Based	2 megawatt-peak (MWp) (fixed tilt)	20 acres	$18 million	$70,000	15	15	273,000	2.7%
	Totals			**$37 million**	**$779,000**	**9.4**		**886,000**	**8.7%**
Unfeasible	Building Integrated PV	x kW - x kW	______	N/A	N/A	N/A	N/A	N/A	N/A
	Hydropower	90 kW	______	$4 million	$30,000	13.5	24	62,000	0.6%
	Anaerobic Digestion - Wastewater Treatment Plant (WWTP)	140,000 gal/day	<1 acre	$840,000	$9,000	23.8	>50	10,000	0.1%
	Geothermal Power Plant	20 MW		$300 million		10.5	15	6,508,000	64.0%
	GSHPs	871 m (borehole length)	0.25 acre	$600,000	$60,000	N/A	N/A	N/A	N/A
	Totals			**$305 million**	**$99,000**	**10.5**		**6,580,000**	**64.7%**

Table ES2 lists the renewable energy practices that will work best at the ANSU site along with their reasons for feasibility. Table ES3 lists unfeasible renewable energy practices and the reasons for that determination.

Table ES2. Feasible renewable energy practices.

Feasible Renewable Energy Practice	Reason for Feasibility
Solar panels (ground-mounted photovoltaic)	Historical weather data suggest the use of photovoltaics is both cost effective and efficient. They can provide a good percentage of the overall power and energy requirement, all located in one area.
Wind turbines	Geography of site indicated much higher wind potential coming from the north than regional mapping suggests.
Solar walls	Easy installation, cost efficient, heating primary need of site.
Solar air collectors	Easy installation; can match a good percentage the high winter heating load.
Solar DHW	Solar insolation data suggest a potential for DHW; this technology will be used for dining facility (DFAC) and barracks to reduce water heating requirements.
Biodiesel	A US Agency for International Development (USAID) and Afghan combined venture is needed to develop this technology application. Biodiesel is more than cost effective than pure diesel, and crops are available to replace poppy production for energy usage. This application will be successful only if specified crops are available year-round for fuel production.
Waste-to-energy - incineration, including biomass material (for power and heat)	This technology would reduce waste by 80–90% and fuel. energy production for a 0.4-MW plant.

Table ES3. Unfeasible renewable energy practices.

Unfeasible Renewable Energy Practice	Reason for Unfeasibility
Solar PV (building-integrated)	Solar PV has inverter reliability problems, high O&M costs, and would provide a limited amount of overall power.
Hydropower	Qargha Dam has an outlet structure and only enough head to provide ~90 kW of energy and an annual production of about 788,400 kWhrs.
Geothermal power plant	High costs for drilling, time required to complete suitable site survey, would prevent a geothermal plant from being operational before ANSU site complete.
Fuel Cells (not listed in Table ES1)	An outside fuel source that is not readily available is required. (Fuel cells cannot use diesel.)
GSHPs	Since almost all buildings require heating only, this expenditure would be cost-ineffective.
Anaerobic Digestion	A simple payback >20 yrs; takes 50 yrs for SIR to be >1 makes this technology economically unfeasible.
WTE - Gasification (not listed in Table ES1)	Extensive labor is required to reduce waste to acceptable size; incineration is a better option.
WTE - Thermal Depolymerization (not listed in Table ES1)	This technology is cost ineffective, high maintenance, and (one product) is only available for much larger-scale waste stream.

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Preface

This study was conducted for North Atlantic Treaty Organization (NATO) Training Mission – Afghanistan (NTM-A)/Combined Security Transition Command – Afghanistan (CSTC-A) under Project Requisition No. 333747, "Afghanistan National Security University Renewable Energy Technology Feasibility Study," via Military Interdepartmental Purchase Request (MIPR) 0GRF1N0032. The technical monitors were LT JG Seth D. Cochran and LT Michael Augustyn, NTM-A/CSTC-A, CJ-ENG.

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was William T. Brown III. Appreciation is owed to US Forces – Afghanistan (USFOR-A) Joint Program Integration Office (JPIO), and the US Army Corps of Engineers (USACE) team members from Afghanistan Engineer District (AED) – North, Transatlantic Division (TAD), Northwestern Division (NWD), Portland District (NWP), the Hydroelectric Design Center (HDC), Geotechnical and Structures Laboratory (GSL), and the US Military Academy, West Point, NY. Franklin H. Holcomb is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the US Army Engineer Research and Development Center (ERDC), US Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Kevin J. Wilson, and the Director of ERDC is Dr. Jeffery P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
British thermal units (International Table)	1,055.056	joules
Btu/gal	0.000279	MJ/L
cubic feet	0.028	cubic meters
cubic inches	1.639	cubic meters
cubic yards	0.765	cubic meters
degrees (angle)	0.0175	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.305	meters
gallons (US liquid)	3.79	cubic meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.025	meters
miles (US statute)	1,609.347	meters
pounds (mass)	0.454	kilograms
square feet	0.093	square meters
square inches	6.452	square meters
square yards	0.836	square meters
tons (2000 pounds, mass)	907.185	kilograms
yards	0.914	meters

1 Introduction

Background

Located roughly 8 miles outside of Kabul in Qargha, the 105-acre Afghanistan National Security University (ANSU) campus will host eight different senior-level educational institutions and courses. This site will be the premiere educational facility for all levels of Afghan National Security Forces, from cadets to senior officers. Planning and design started in late 2008 and continued through early 2010. Construction began in April 2010 and should be completed by the fall of 2012. On completion, the ANSU will be the home of the Afghan National Security University Headquarters, the National Military Academy of Afghanistan (NMAA), the Afghan Army National Command and Staff College, the War College, the Bridmal Academy for senior non-commissioned officer courses, the Religious Cultural Affairs Course, Legal School, the Foreign Language Institute, and the Counterinsurgency Training Center. One of the biggest motivators for building this complex is to promote a homogenous military identity. All facets of the military and the police force who receive schooling at the complex can share experiences, which will strengthen the security of the country (Martinez 2010).

A primary concern of building such a large site is how to meet the energy demand and power consumption required to operate the complex. It will take careful planning to determine the most cost-effective and reliable way to deliver the required power to serve the needs of a daily population of 8000 personnel, i.e., to satisfy a peak demand of nearly 16 MW (via the use of a 20-MW total diesel generator capacity). Current plans are to the run site on diesel-fueled electrical generator power, at an estimated annual fuel cost of $45M. Alternative energy solutions can provide the means to reduce daily operating costs, to alleviate the dependency on fossil fuels, and to simplify Operations and Maintenance (O&M), to ease the transition from coalition forces to host nation personnel, who will eventually assume responsibility for maintaining the campus and its support facilities.

This work was undertaken to assist US Forces – Afghanistan (USFOR-A), Joint Program Integration Office (JPIO) in reviewing and determining the feasibility of a number of renewable technologies available to ANSU.

Objectives

The objective of this work was review and evaluate the feasibility of commercially available renewable energy technologies for application at ANSU and its supporting facilities located in Qargha, Kabul, Afghanistan, to reduce the use of, or to replace fossil (diesel) fueled electrical generators.

Approach

This study divided the project into four phases: (1) data acquisition, (2) data analysis, (3) the final report, and (4) an onsite or VTC out-brief. The study was accomplished in the following stages:

1. Data about the ANSU site (planning and design documents) were acquired from the US Department of Energy, Kabul International Airport, the Afghan Ministry of Energy and Water, "open-source" maps, and other reliable external sources.
2. Each of the following renewable technologies was analyzed to determining whether it should be included in the diesel energy reduction plan:
   a. solar photovoltaic (ground-mounted and building-integrated)
   b. solar domestic hot water (DHW)
   c. wind
   d. geothermal
   e. geothermal (ground-source) heat pumps (GSHPs)
   f. waste-to energy (WTE), which includes biomass
   g. fuel cells
   h. solar air collector
   i. solar air ventilation
   j. hydroelectric power (potentially supplied by the nearby Qargha Dam).
3. The feasibility report included recommendations for each technology, explanation of the findings, notional equipment, installation, operation and maintenance costs, and payback estimates based on US regional and local costs with the given "Afghanistan construction cost multiplier" of three.
4. Energy-saving best practices were included to support facility planning and design. Baseline cost estimates for the recommended technologies were included to provide an informed, financially sound decision for each technology evaluated. These financial estimates were based on the given local cost factor multiplier, and include simple payback calculations.
5. A formal out-brief by the research team to the senior leadership of JPIO and NTM-A/CSTC-A.

Table 1 lists the project timeline during the course of the study.

Table 1. Project timeline.

Milestone	Date
Full proposal submitted to JPIO	30 June-2010
Data request submitted to JPIO	30 June-2010
Funding Received	18 July-2010
Data collected by JPIO	16 July 2010
Data submitted to USACE/ ERDC	23 July 2010
Draft report	23 August 2010
Final report	15 October 2010
Outbrief in Kabul	08 November 2010

Scope

Assumptions

This feasibility study assumed that:

- The peak population of 2400-NMAA cadet population fluctuates throughout the year due to academic sessions and training requirements.
- For water consumption rates, NMAA feeds all cadets three times a day.
- All phases of construction will either be completed on time, or if they "slip," the schedule change will not affect the implementation of these recommended solutions.
- Based on command guidance, only the following buildings/areas or rooms) will receive year-round air-conditioning:
    - ANSU HQ Bldg
    - The Medical Clinic Bldg
    - Senior officer quarters
    - Information technology (IT) rooms
    - General Officer offices.
- The Afghanistan construction cost factor of three for all technology purchases is accurate (This factor includes all JPIO overhead rates from either USACE or Air Force Center for Engineering and the Environment [AFCEE], acting as the construction agent). This factor is used to estimate the cost of constructing in Afghanistan relative to construction costs for the United States; it is based on recent construction costs in Afghanistan and the expertise within the JPIO and AED.

- The current solar and wind data taken from the Kabul International Airport is an accurate reflection of the ANSU complex, roughly 8 miles West from the airport. (See Appendix A for wind data.)
- Due to transportation and security issues, delivery and setup of the renewable technology systems in Afghanistan will likely take more time than comparable activities in the Continental United States (CONUS).
- O&M will be initially completed by a contractor until host country personnel are trained to standard on O&M for all technologies.
- Due to the anticipated delays in transporting materials and supplies, replacement parts may not be available when needed. Therefore, it is important to have selected spare parts on hand.
- Hydropower assumptions are referenced in Appendix B of the report.
- Although it is anticipated that the ANSU student body and staff will grow in the future, the rate and ultimate size outcome of that growth are currently unknown; this work does not account for that growth.
- Although JPIO/CSTC-A may consider demonstrating other renewable technologies (not completely ready for commercial use) for educational or pilot programs, this feasibility study does not be considered those technologies. (An unproven technology is defined as one that has not proven itself in an operational environment with corresponding data for at least 1 yr.)
- No major changes could be made to the buildings during Phase I because construction had already started.
- Building footprints for Phases II and III cannot be altered.
- Information from the Qargha Dam limited the US Army Corps of Engineers Hydroelectric Design Center (USACE HDC) from providing more analysis (see Appendix B).
- All technologies must be built onsite to eliminate the need for additional fencing and security for an off-site location.
- Renewable technologies were also considered for use by NMAA cadets as part of their senior-level final projects.

Planning factors

- There is a 12–16MW peak demand for the ANSU facilities.
- The fully burdened cost of fuel (FBCF) is $4.40/gal ($1.16/L). However, this work also used $10/gal and $20/gal as part of the sensitivity analysis.

- The daily population will peak at ~8000, roughly 2400 will live at the complex.
- A value of 300 sq ft of conditioned space per ton was used to calculate cooling requirements.
- The annual cost of diesel fuel to run the generators is estimated at $45 million, based on:
  - two diesel fuel tanks, each at 800,800 L capacity, to provide a 14-day (or 2-week) supply of fuel.
  - and the annual diesel fuel consumption, calculated to be:

    two tanks * 800,800 L /tank/2 wks * 4 wks/mo * 12 mo/yr = 38,438,400 L/yr.

    which is used to calculate the annual diesel fuel cost:

    $1.16/L * 38,438,400 L/yr = $44,588, 544, or about $45 million/yr.
- Diesel fuel provides energy of approximately 12.7 kWh/gal, based on a 62.5 percent average load factor for a 1 MW diesel generator.*
- The peak demand factor for the complex is 90 percent (Abushakra et al. 2001).
- The water demand at the site is 18–20 gal/person/day.
- Solid waste generation is 4 lb/person/day (extrapolated from the US Environmental Protection Agency (USEPA) calculation of US Municipal Solid Waste (MSW) generation in 2009 of ~4.3 lb of waste/person/day (USEPA 2011).
- Using a base of 65 °F, Kabul experiences 759 cooling degree-days (CDD) and 4172 heating-degree-days (HDD).
- Kabul elevation is 5876 ft. Elevation of the ANSU complex is 6500 ft.
- This study analyzed and recommended commercially-available renewable energy technology only.
- The interest rate is approximately 4 percent.

Project limitations

Due to the conditions in Afghanistan, data collection was limited to the analysis of commercially available technologies only (described in Appendix C). Early in the project, there was discussion of whether to consider the option to use a compact nuclear power plant. However, internal debate quickly eliminated this as an option for analysis.

* Based on an Ascension Island study (USDOE 2001), there are 0.0833 gal/kWh for diesel fuel. In the case of the ANSU study, a 1-MW diesel generator uses 0.0864 gal/kWh at 25% load factor, and 0.0711 gal/kWh at 100% load factor. Taking the average load factor of 62.5%, the corresponding average is 0.07875 gal/kWh, which also equates to 12.7 kWh/gal for diesel fuel.

It was also decided to exclude attempts to implement unproven (noncommercial) technologies, which may not be able to provide the required energy output and reliability, and which would discredit the validity of this study. For the purposes of this project, it would be irresponsible to recommend and install unproven technologies without successfully demonstrating it for at least 1 yr with positive results. This being said, the NMAA could — as part of a technology demonstration — leverage the cadet senior-level project program and install some of these small-scale (unproven, yet emerging) technologies for educational purposes. Appendix D outlines some emerging renewable energy technologies that are not yet commercially available.

This report also contains recommendations for data that must be acquired before placement of certain technologies. For security reasons, all technologies should be located within the ANSU complex. Conversely, if energy-generating technologies are to be located outside the complex, additional security should be provided at that location. It is possible that large energy-generating renewable technologies that have the potential to provide a sizable percentage could be built outside the ANSU Complex, and that power could be transmitted to ANSU through distribution lines. Such an arrangement may eliminate the need for additional fencing or land acquisition, and would also reduce the daily transportation of fuel and materials into the site.

Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2 Project Execution

Data collection

The following data was received from JPIO:

- cost of fuel or electrical generation($/gal or $/kWh)
- notional load factor of building electrical and thermal demand
- site layout to scale
- building inventory and square footages, including master plan of the ANSU complex
- construction phases and timetable
- type and size of heating, ventilating, and air-conditioning (HVAC) equipment in buildings
- site elevations and surrounding area (~1km beyond fence line).

The following information was collected from NASA and 14th Air Force Weather Squadron:

- solar data from Kabul International Airport
- wind data from Kabul International Airport.

The following information was collected from Open Source information searches:

- water flow downstream of Qargha Dam
- estimated elevation differential between Qargha Dam and the ANSU complex.

The study team also requested, but did not receive, the following data:*

- elevation of water source (lake) and the ANSU complex
- origin, current uses, yearly and monthly flow records (or estimate if records not available), location, and connection to source and support details of existing 10-in. piping
- existing uses and water rights of source
- hydrologic data for water source, including (but not limited) to yearly and monthly lake inflows, outflows, elevation, drainage area, etc.

* Note that, in absence of the data, reasonable assumptions were made.

- meteorological data for the source area/drainage
- topographic maps of area, encompassing at least the ANSU complex and water source
- location of other potential water sources nearby and their hydrologic data
- geologic maps of areas encompassing ANSU complex and water source
- planning factors for the design of ANSU Phase I.

Data analysis

Solar domestic hot water

Technology description

Solar DHW uses the sun's energy to heat water and then to store it until required. The system is composed of two main parts: a solar collector and a storage tank. The collector is a small flat box with a clear cover facing the sun. Inside the box are small tubes in which a fluid, usually water, passes through continuously. The tubes are attached to a dark absorber plate, typically a metal (steel, copper, or aluminum), that absorbs solar radiation, converting it to heat. As this device heats up, the fluid absorbs the heat as it passes through the tubes. A well insulated tank stores the heat transfer fluid. In areas that have no freezing temperatures, water passes through the collector, then the heated water is merely deposited into the tank and re-circulated. In areas with freezing temperatures, a water-propylene-glycol mix is used, which then passes through a coil and exchanges heat with the water in the tank. Ideally, anywhere hot water is needed, it would be preheated with a solar hot water collector/storage tank system, and fed into the electric water heater.

Existing use

Solar hot water is a mature technology that has the ability to be used in a variety of diverse environments and applications. Solar hot water has been used for years, especially for swimming pools where the temperature does not have to be that high. Since the 1970s, there have been great technical advances in the solar water heating process to reduce costs. Solar water heating has become efficient enough to use in heating water for houses. Depending on location, home rooftop systems can provide 30–80 percent

of the hot water heating demand. In the winter, solar water heating is not as effective in producing the amount of hot water needed.

There are solar already hot water projects in operation in Afghanistan. A solar-electric hot water system was installed at the Hope House Orphanage in February 2010 (Australian DOD 2010), and the Khorasan House Orphanage received a solar water system and a 900-W photovoltaic lighting system in March 2010 (INM 2010).

Viability for ANSU

When assessing the potential usage of solar water heating, it is important to understand that the annual savings will not be evenly distributed throughout the year; the summer months will see the maximum benefit of solar water heating while the winter months will be significantly less. The overall intent is to lower fuel costs and save money. At the FBCF of $4.40/gal, solar water heating can accomplish this.

Also important in determining the viability of solar water heating is the amount required in each building. Additionally, the work schedule of the complex must be taken into consideration. The National Military Academy of Afghanistan operates on a rigid timeline, similar to the US Military Academy at West Point. As a result, hot water demand will spike in two or three distinct points during the day, i.e., the cadets will be using the facilities around the time each day, stressing the system. This static schedule allows very little time to heat enough water via the solar water heaters, hence the need for proper storage and for a secondary water-heating system to augment the solar water heating. So long as there is an understanding that solar water heating cannot operate as a standalone system, it will provide sufficient potential to reduce energy consumption on the complex, especially during the summer months, to make solar water heating a feasible technology at ANSU.

Solution

Using the baseline expectation of 10 gal of hot water per person each day, the roughly 2400 cadets at NMAA require 24,000 gal/day. Factoring in the remaining 5600 personnel on the site, with a demand of 7 gal per day, results in a rough total of 63,200 gal of hot water per day. Recognizing that the hot water will be used most at the barracks, the DFAC, and the gymna-

siums, installing solar hot water heaters on these buildings provides the greatest reduction in diesel consumption. These devices can be either installed on the roofs of the buildings, or ground mounted depending on roof location, pitch, and solar access.

Savings

It will take 12.7 kWh/gal of diesel fuel to run an electrical resistance hot water heater (based on 62.5 percent load factor for a 1-MW diesel generator). To provide hot water for the DFAC to provide three meals per day for 2400 personnel, it will require 193.8 gal of diesel fuel each day. This translates into an annual heating consumption of 70,737 gal of fuel per year. With the FBCF at $4.40/gal, the annual hot water heating fuel savings for the DFAC is $311,240. To provide hot water for the barracks with enough heat from 1100 rooms, it will require 258.08 gal of diesel fuel per day. This translates into an annual heating consumption of 94,200 gal of fuel per year. With the FBCF at $4.40/gal, the annual hot water fuel savings for the barracks is $414,480. The total annual fuel savings is therefore $725,720.

Investment

Table 2 lists solar water heating investment details.

Table 2. Solar water heating investment details.

Location	Estimated Hot Water Use L/d	Size m^2	Cost w/o multiplier	O&M cost w/o multiplier
DFAC	109,200	1,117	$1,145,632	$5,000 (total)
Barracks	145,169	1,489	$1,498,894	

Simple payback

Table 3 lists simple payback for solar water heating.

Table 3. Simple payback solar water heating.

Simple Payback (yrs)	$4.40/gal	$10/gal	$20/gal
DFAC	11.04	4.86	2.43
Barracks	10.85	4.77	2.39

Savings to investment ratio (SIR)

Table 4 lists the SIR for solar water heating.

Table 4. Solar water heating SIR.

SIR (yrs)	DFAC			Barracks		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.39	0.91	1.82	0.40	0.93	1.86
10	0.72	1.65	3.32	0.73	1.69	3.38
15	0.98	2.26	4.55	1.01	2.31	4.64
20	1.20	2.77	5.56	1.23	2.82	5.67
25	1.38	3.18	6.40	1.41	3.25	6.52
50	1.90	4.37	8.80	1.94	4.46	8.96

Long-term considerations (O&M, complexities, replacement parts, labor skill)

Afghanistan has already demonstrated that it is capable of using and maintaining solar water heaters throughout the country. The O&M budget is minimal for a solar water heating project, provided the heated fluid is composed of a mixture of antifreeze and water to prevent from freezing inside the pipes. An alternative system uses captive water drain-back to prevent freezing, requiring less maintenance of the heat transfer fluid. Maintaining the system is not complicated and will require little training to ensure competent maintenance can be done by the onsite crews. Replacement parts for the solar water heating system include valves and fittings, a water pump, temperature sensors, and differential controller with an estimated shelf life of 10 yrs. Purchasing these parts ahead of the scheduled maintenance time provides flexibility in changing the parts out, and will save time and money. To eliminate the potential for freezing, solar air panels are recommended with an air/water heat exchanger to circulate water into the solar storage tank.

Solar photovoltaic (ground-mounted)

Technology description

Photovoltaic cells (PV) convert sunlight directly into electrical energy. The PV effect refers to the process where photons excite electrons into a higher state of energy upon collision to create electricity. There are a variety of

methods of production to create a PV cell, and the industry continues to advance. This is a mature and proven renewable energy technology.

The two main methods to introduce photovoltaics to a site are:

1. Building-integrated PV (BIPV) systems, in which the PV cells are part of the roof structure
2. Standalone systems, such as a PV array, where the panels are mounted onto the ground.

Figures 1 and 2 show examples of large utility-scale DOD ground-mounted PV systems.

Figure 1. A 2-megawatt-peak (MWp) PV system at Fort Carson, CO.

Figure 2. A 14-MWp PV system at Nellis AFB, NV.

To maximize the effectiveness of the PV array, the PV cell must be perpendicular to the sun's insolation. This is accomplished through the use of a solar tracker. Trackers (both manual and automated) adjust the PV panels based on the time of day and the time of year. A single-axis tracker adjusts for time of day, whereas a dual-axis tracker adjusts for time of day and time of year. By adjusting PV arrays, a 20–50 percent increase in electricity can be obtained depending on the season of use. If automated solar tracking is not available, then manually setting the panels at the angle of latitude is recommended.

Existing use

PV arrays are the most recognizable and ubiquitous technologies investigated in this study. The scalability of arrays makes it one of the most versatile technologies as well. PV arrays can be found on the roofs of houses, providing a couple hundred kWh/yr, up to solar farms using acres of solar panels in areas of high solar insolation. The modularity of these systems increases their potential for usage.

As a conservative rule-of-thumb, it takes an area of approximately 7 to 10 acres to accommodate 1 megawatt-peak (MWp) of installed PV array (axis-tracking, smaller area required for non-tracking or fixed arrays). Figure 3 shows the winter shading effect that determines the row spacing for large solar farms and ultimately results in the area per MWp rule. The ANSU site shows a plan for 10 acres per MWp to accommodate PV panels at latitude tilt (40°) to eliminate winter shading.

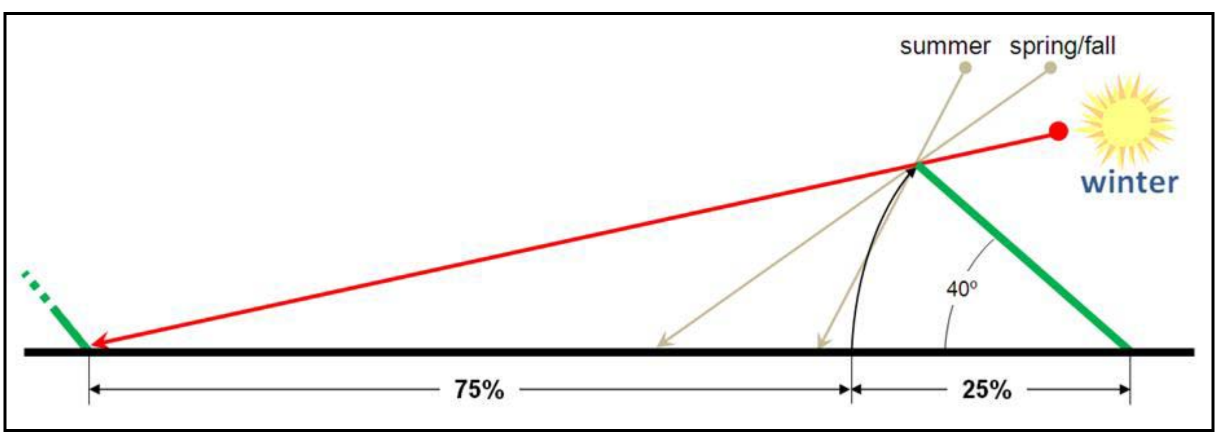


Figure 3. Winter shading effect for PV array at 40 degrees.

Currently, the US Agency for International Development (USAID) and other Non-Government Organizations (NGOs) are working throughout Afghanistan using PV panels and small arrays to provide electricity in remote locations incapable of connecting to the grid. The National Renewable Energy Laboratory (NREL) has done extensive solar mapping of Afghanistan already, with maps of the entire country for both seasonal and annual solar radiation levels (Appendix E provides the solar map of Afghanistan developed by NREL). Unlike regional wind speed data, solar data are less dependent on topography and precise location. This allows the maps to provide the basis for solar calculations.

The US military has already invested in solar technology in Afghanistan. The “22 Bunkers” Project, located East of Kabul, demonstrates the potential benefits of small-scale standalone system. This project was commissioned in February 2010. Five systems — 8 kilowatts-peak (kWp) each — were installed on the project to provide energy security for guard towers and security facilities on the site. This small scale project’s goal is to identify the simple payback period, SIR, energy efficiency, and feasibility of using photovoltaic systems at other Afghan National Army facilities. Leveraging the knowledge gained at this site makes solar power a viable option for ANSU complex. While this project does not include building-integrated photovoltaics, the results do prove that there is a positive potential for PV use in Afghanistan.

The most significant inhibitor to the success of PV panels in Afghanistan is system maintenance. Of paramount importance is to ensure those responsible for the integrity of the system are equipped with both the tools and the knowledge to troubleshoot and repair the systems. If tracking systems are used, the tracking mechanisms must operate as designed. Additionally, it is important to keep the panels clean to maximize exposure to the sun; this factor will also affect the payback timeline.

Viability for ANSU

The analysis of solar data for Kabul and the reports from the demonstration of solar power by NGOs and the “22 Bunkers” complex, indicate that ground-mounted PV power is a viable option. Additionally, the ability to format the size of the arrays makes the technology versatile enough to provide a greater amount of power than some of the other options. While

there are locations in Afghanistan where solar power has a greater production potential, the insolation levels at ANSU are high enough to make solar power an option for the site. When assessing the potential of a large-scale PV array on the complex, additional considerations must be factored, most notably land. The facility master plan must be evaluated to determine the best location for the PV array. At night, other sources of electricity are needed since PV is not a constant source of power.

Solution

When developing the photovoltaic plan for the complex, significant factors include available land area available, solar access, and maximum solar generation before causing grid instability.

Using the data from Table 2 as the metric, each megawatt of installed solar power yields the monthly productions listed in MWh (Table 6). Therefore, the total annual electrical generation from a 1-MWp PV array at fixed latitude tilt is 1731.2 MWh.

Savings

Assessing the estimates for 1-MWp installed solar potential, the annual savings could be higher or lower, depending on solar availability and proper maintenance for that particular year. Additionally, one other concern is whether the standalone arrays should be fixed platforms set at latitude, or dual axis rotating panels that follow the sun's path through the day, ensuring maximum panel exposure at all times. Dual axis panels are more expensive to install and require more maintenance, but are 40 percent more efficient. Table 7 lists the savings of a 1-MWp and 2-MWp system, for comparison, based on array size, mounting equipment, and the FBCF.

Table 5. Kabul monthly insolation.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Insolation* (kWh/m²/day)	2.29**	2.83	3.86	5.06	6.38	7.40	7.30	6.67	5.66	4.23	2.95	2.17

* Kabul, Afghanistan - 34.53 degrees north latitude

** These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002 (also called peak-sun-hours)

Table 6. 1 MWp installed solar potential (MWh).

Jan	Feb	Mar	Apr	May	Jun
70.99	79.24	119.66	151.80	197.78	222.00
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
226.30	206.77	169.80	131.13	88.50	67.27

Table 7. Anticipated savings solar arrays.

$/gal oil	4.4	10	20
1 MWp fixed	$599,716	$1,362,990	$2,725,980
2 MWp fixed	$1,199,431	$2,725,980	$5,451,960
1 MWp dual	$839,599	$1,908,180	$3,816,360
2 MWp dual	$1,679,203	$3,816,370	$7,632,740

Investment

Depending on the system, the investment will range from $3/watt-peak (Wp) for a 2-MWp or greater fixed array, to $6/Wp for a 1-MWp dual axis array (all in US costs). Factoring in the Afghan cost factor multiplier of three; the anticipated cost should vary between $9–$18/Wp (Table 8). Additional costs are incurred for O&M for the dual axis arrays, but the 40 percent increase in efficiency should easily cover that difference. O&M costs of roughly $0.035/Wp annually will cost $35,000/yr for each MWp installed (Afghan costs). In the case of the dual axis array, its O&M costs include an additional $0.05/Wp annually, or $50,000/yr for each Wp installed, for servicing mechanical components for the dual axis. Finally, each MWp of solar panels will require roughly 435,000 sq ft of ground space, or about 10 acres.

Table 8. Solar investment breakdown per MWp installed.

	1 MWp Fixed*	2 MWp Fixed	1 MWp Dual Axis	2 MWp Dual Axis
Installed (Afghan Cost)	$12,000,000	$9,000,000	$18,000,000	$15,000,000
O&M (Afghan Cost)	$35,000	$35,000	$85,000	$85,000
Land Use (Acres)	10	20	10	20
*Note that costs do not include tax incentives or (Federal or State) Government subsidies.				

Simple payback

Table 9 list the results of simple payback calculations for solar array systems.

Table 9. Simple payback for solar array systems.

Simple payback (yrs)	$4.40/gal	$10/gal	$20/gal
1 MWp fixed	20.01	8.80	4.40
2 MWp fixed	15.01	6.60	3.30
1 MWp dual	21.44	9.43	4.72
2 MWp dual	17.87	7.86	3.93

SIR

Table 10 lists the SIR for fixed axis systems, and Table 11 lists the SIR values for dual axis systems. These data show that, assuming a 4 percent interest rate, the 2-MWp dual axis has a SIR value greater than 1 in 15 yrs based on the current FBCF.

Table 10. Fixed axis SIR.

SIR (yrs)	1 MWp fixed axis			2 MWp fixed axis		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.21	0.49	1.00	0.42	0.99	2.00
10	0.38	0.90	1.82	0.76	1.80	3.64
15	0.52	1.23	2.49	1.05	2.46	4.99
20	0.64	1.50	3.05	1.28	3.01	6.10
25	0.74	1.73	3.50	1.47	3.46	7.01
50	1.01	2.38	4.82	2.02	4.75	9.63

Table 11. Dual axis SIR.

SIR (yrs)	1 MW dual axis			2MW dual axis		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.19	0.45	0.92	0.22	0.54	1.11
10	0.34	0.82	1.68	0.41	0.99	2.02
15	0.47	1.13	2.30	0.56	1.35	2.77
20	0.57	1.38	2.82	0.68	1.65	3.38
25	0.65	1.58	3.24	0.79	1.90	3.89
50	0.90	2.18	4.45	1.08	2.61	5.34

Long-term considerations (O&M, complexities, replacement parts, labor skill)

With proper maintenance, a PV system will last over 30 yrs. It is recommended t0 maintain at least 5 percent replacement PV panels for wind/hail/storm/other damage, and also to keep a spare inverter on-hand. (An inoperable inverter equates to no electricity.) O&M is minimal; check for proper operation on a weekly basis; check panel electrical connections on an annual basis. Skills needed are an electrician to check panel connections, voltages, and inverter, and skills needed to repair/replace an inverter. Electricians are also needed to replace any bad PV panels in the array.

Building-integrated PV

Technology description

A “Building Integrated Photovoltaic” or “BIPV” (system) is the term used to describe PV systems that are part of a new building design, most commonly on (both flat and pitched) roofs. However, it is not always necessary to install a BIPV system during the construction of a new building, because they can be added later as a retrofit or included as part of a roof replacement for an older building. In the northern hemisphere, BIPV systems are generally installed on south-facing pitched roofs or on all the available surface area of a flat roof. These systems usually consist of thin-film amorphous silicon cells that are readily combined with a conventional membrane roofing material for flat roofs, or between the seams of a standing seam metal roof system (Figure 4). Perhaps the most significant advantage of BIPV systems is that they can be used in locations where there is no available space on the ground, which does not seem to be a factor for the ANSU complex. Because they are often installed on roofs that are not optimally oriented towards the sun, the maximum output for a BIPV system is usually derated, sometimes by as much as 30 percent.

Two basic commercialized PV modules are currently available to the public. Thick crystal products include solar cells made from crystalline silicon either as single or poly-crystalline wafers deliver about 10–12W/sq ft of PV array. There are also thin-film products that incorporate thin layers of PV material placed on a glass superstrate or metal substrate. These thin-film materials deliver about 4–5 watts per sq ft of PV array area. Due to the lower requirements for active materials in comparison to thick-crystal products, thin-film technologies have a higher promise of cost efficiency.

Figure 4. Two 30-kWp BIPV replacement flat roofs on the installation Library and a warehouse facility at Fort Huachuca, AZ.

Figure 5. A 15-kWp pitched standing seam metal replacement roof on Bldg 84 at Kilauea Military Camp, HI. Also shown is the 15-kW DC-to-AC inverter at KMC Bldg 84.

BIPV systems are generally interconnected with the local utility grid. For grid-connected systems, power conditioning equipment called an inverter (Figure 5) is located near the electrical panel, which converts the direct current electricity generated by the BIPV system into utility-compatible alternating current. Some BIPV systems include battery storage that can store excess capacity electricity generated during the day (beyond that which serves facility loads). The stored electricity is then used during power outages or when no sun is available, e.g., at night or during overcast weather conditions.

Existing usage

Over the past several years, the US Department of Defense has demonstrated a number of small BIPV systems, including those shown in the photos above. DOD demonstrations of the more conventional single-crystal and poly-crystalline PV technologies on roof-mounted systems are simply considered as “add-on” systems rather than “BIPV” systems. Some of these look very much like their ground-mounted counterparts, except

that they are installed on a flat roof instead of the ground. Still, whether they use a BIPV or “add-on” type configuration, these systems are still overcoming developmental challenges.

Some drawbacks of these systems are worthy of note. Typically, the inverter has been the weak link for these small systems. Roof penetrations for the mounting hardware for “add-on” roof mounted systems have almost always caused relatively rapid deterioration of the roof’s integrity, resulting in leaks. Also, economies of scale are harder to achieve with these smaller systems, despite the large number that have been installed. Overall, the DOD experience with large ground-mounted, utility-scale systems, like the ones discussed earlier, has been much more positive, both from an operational and economic perspective.

Solution (by building)

BIPV systems are commercially available. However, due to reliability issues (primarily related to the inverter and other maintenance issues), implementation of this system is not recommended at this time. The BIPV approach to installing large-scale PV systems (like those assessed for ANSU) is still faced with many difficult challenges that are often worsened when combined with roof mounting. Problems of multi-megawatt-peak PV systems are much more easily resolved when the solar array is located in one central ground location, away from the loads that are being served. BIPV systems are always a viable consideration when space is at a premium, but that it not the case at ANSU. In addition, it is best to minimize O&M challenges for a local maintenance staff that may not yet be familiar with PV technology. Expecting local maintenance personnel to be responsible for many rooftop systems spread out over the entire ANSU campus would add greatly to their already challenging duties. Finally, if a BIPV system is installed, it would eliminate the need for some of the mounting hardware and structural systems, yet the efficiency of the PV, which is flush to the flat roofs, is much lower than an angled panel set at the latitude of the site approximately 34.5 degrees North, and lower still than the efficiency of a tracking system that rotates the panels with the sun.

Additionally, unless the vast majority of the buildings on the ANSU site were fitted with BIPV systems, the application would supply only a small percentage of the total ANSU demand (kW vs. MW).

However, this study recommends a small-scale BIPV demonstration project on the NMAA site for the cadets to do senior-level projects. This would be an excellent application of this system.

Investment, savings, simple payback, and SIR

A quantitative economic analysis is not included here due to the reasons listed above.

Long-term considerations (O&M, complexities, replacement parts, labor skill)

Previous DOD experience and the issues noted above indicate that the implementation of BIPV systems at this location would incur extensive and expensive O&M costs. Additionally, it would require highly trained and skilled personnel to operate and maintain these systems properly.

Wind

Technology description

Wind turbines harness the wind and convert it into electrical energy. Wind turbines are generally mounted 100 ft or more above the surface where the wind is faster and less turbulent than at ground level. Wind turbines can be erected as standalone systems or grouped together in “wind farms.” Turbine placement is vital for successful power generation. While it is possible to assess the productivity of a particular area in Afghanistan on a regional basis, a site-specific assessment will provide the greatest possibility to maximize the power output of each turbine.

Existing usage

Wind turbines are widely used in the United States, Asia, and Europe. It is a mature renewable energy technology.

Currently, there are wind initiatives in Afghanistan. USAID has already invested in limited wind energy projects, most notably in Herat, where there are approximately 120 windy days each year acceptable for power production. On a smaller scale, wind turbines are providing the power for irrigation pumps throughout the country. Using wind turbines, and other renewable projects, has given remote villages access to electricity for the first time. However, given the scale of the project, the wind turbines used

at the ANSU complex must provide much more energy to achieve the same effect. There is also a USACE project located east of Kabul at the "22 Bunkers" Complex. Working in concert with a photovoltaic array, the combination of solar and wind power provides the energy requirements for one of the primary guard towers. Leveraging the data from this site will help to develop a plan for the ANSU complex.

Refer to Appendix A to see the projected locations of wind turbines for maximum effectiveness.

Viability for ANSU

To properly determine if wind power is a viable option for the ANSU complex, walking the terrain is one of the best methods if instruments and data are limited. However, the best method is to conduct a mid- to long-term wind study using proper data gathering instrumentation. Using the regional data collected by USAID and NREL, wind data taken from the Kabul International Airport, as well as topographical maps of the region, it is possible to predict with a high level of accuracy the best placement for a wind turbine (Appendix E provides a wind map of Afghanistan developed by NREL). There are still some details that cannot be accounted for without a site-specific assessment to determine the exact location. While the winds are generally predictable, placement of wind turbines is as much art as science.

Looking at the regional data for Afghanistan provided by USAID and NREL, Kabul is located in an area with poor to marginal wind power. The biggest potential for a large scale wind farm is near the Iranian border where wind speeds are excellent for wind power. Based on regional wind maps, the greater Kabul area is not a prime location for wind power, and a more specific assessment is needed. It is not the intent of the ANSU to become a defense university and a wind farm. Rather, the goal is to provide some turbines capable of producing enough power to offset much of the diesel fuel usage.

The wind data gathered at the Kabul International Airport, approximately 8 miles from the center of the ANSU complex, depicts an average wind speed of 6.14 m/s. The winds are fastest during the winter months from

November to April. This data suggest that the airport should actually be categorized as Wind Power Class 3 (moderate wind potential).*

To fully understand the potential of the site for wind power, the topography of the site must be assessed. Kabul is located in a valley. Large mountains delineate this to the West and East most directly, with the North becoming mountainous roughly 50 miles away. Closer to the airport are hills that border both the North and West, rising up 200–400m. The wind then follows the path of least resistance between the mountains, not over the top. There are two paths through which wind can flow easily, one in the north between two crests, and one to the West where route 76 passes through. This results in the winds coming predominately from the North and Northwest.

Applying this same level of analysis to the ANSU, determining the likely path of the wind will help to reduce costs associated with taking additional data to confirm the results.

The ANSU, which sits almost due West from the airport, is outside of the rising hills, which barricade the airport. Rather, the ANSU location is blocked to the North by lower hills. These hills extend northward to the East and West creating a natural funnel for the dominant Northern winds to travel. The winds will likely be forced through the lowest point at the base of the funnel. Additionally, some of the wind may sweep around the funnel and be channeled into the complex from the Northwest, along the same route the Qargha Dam empties. Because of the geography of the site, the conventional wisdom of putting the wind turbines on the top of the hill may produce less energy than a turbine placed in the valley, as is the case here.

Unfortunately, it is impossible to definitively state where the turbine should be placed through the use of maps alone. Vegetation can be used to channel the wind as well, and this cannot be determined on a map. Note that the vegetation if assumed to be sparse on this site due to actual ground reconnaissance by one team member. Overall, site specific evidence of the ANSU terrain, in conjunction with the wind rose data from the Kabul International Airport only 8 miles away challenges the regional

* US Department of Energy (USDOE) classifies wind power on a scale of 1 to 5 with 5 as the strongest.

assessments for the Kabul area. 1-MW wind turbines are a viable option for the site, but placement will be essential in the successful production of power for the complex. Wind power can likely generate 3–5 percent of the power required for the campus, though more wind data must be gathered on the site itself to be sure.

Solution

With the potential for wind power to provide a solid source of energy for the site, the next phase needs to gather wind data from the points recommended in this study. Additionally, walking the complex may suggest additional locations to take measurements of wind speed. Installing a 10-kW wind turbine on a 165-ft tower costs approximately the same as it would to set up an anemometer. Thus, it may be beneficial to install smaller wind turbines initially to check the conditions and generate power to help complete the construction of the complex. After enough time, should the data suggest that larger wind turbines would thrive in these areas, upgrade to the larger turbines.

Based on all the information available, personal experience, and topography available for the region, two potential areas on the complex have the potential to produce larger than expected wind power results. Figure A2 shows the two locations where wind data should be taken. Location A is 34° 33' 5.25" N 69° 4' 33.37" E and location B is 34° 33' 21.3" N 69° 3' 44.4" E. These are topographic estimates of where wind power should be at its peak. Based on the actual site conditions and vegetation, the precision of the results of this study may vary. Even though the wind will be faster near those points of interest, determining the actual test locations and final placement of the turbine can best be determined by an engineer on the ground. Note that a wind study at these locations would be an excellent NMAA cadet senior-level project.

Savings

To get a true estimate of the potential savings from installation, onsite measurements of wind speed must be completed. However, using the data that is currently available from the Kabul International Airport, which is only 8 miles away with similar elevation and geography, a realistic and possibly conservative estimate is obtained. Using the 1-MW Nordic Windpower N1000 59m diameter turbine, with an average wind speed of

6.14m/s annually, there is anticipated annual energy production of 2122 MWh. Based on the FBCF of $4.40/gal, there is an annual savings of $735,181. This is an annual fuel reduction of 1.65 percent.

Investment

Given the Afghan construction cost factor multiplier of three, the Nordic 1000 will cost between $5 and $6 million. There will be O&M costs of $60K annually (adjusted for Afghanistan) associated with the 1-MW wind turbine. Additional costs will be incurred for training of Afghani personnel to use and maintain the turbines, but this is anticipated for all the technologies being leveraged at the complex.

Simple payback

Table 12 lists the results of simple payback calculations for the Nordic N1000 turbine.

Table 12. Simple payback for the Nordic N1000 turbine.

Simple payback (yrs)	$4.40/gal	$10/gal	$20/gal
$5M turbine	6.80	2.99	1.50
$6M turbine	8.16	3.59	1.80

SIR

Table 13 lists the SIR for the Nordic N1000 turbine.

Table 13. SIR for the Nordic N1000 turbine.

SIR (yrs)	$5M turbine			$6M turbine		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.59	1.42	2.91	0.49	1.18	2.42
10	1.07	2.59	5.30	0.89	2.16	4.42
15	1.47	3.55	7.26	1.22	2.96	6.05
20	1.79	4.34	8.88	1.50	3.61	7.40
25	2.06	4.99	10.21	1.72	4.16	8.51
50	2.84	6.86	14.04	2.36	5.71	11.70

Long-term considerations (O&M, complexities, replacement parts, labor skill)

The long-term considerations for wind turbines depend on the specific wind turbine. One company (Northern Power) produces wind turbines that have no gears and therefore require less maintenance on an annual basis. Another company (Nordic) that makes a two-blade turbine that is easier to install and requires a smaller crane to service.

All types of turbines require annual maintenance. Wind turbine O&M personnel must have specific training; if no trained personnel is available and a wind turbine fails, it will not produce power (best-case), or it may experience catastrophic failure (worst-case). This study recommends Northern Power for its low-maintenance technology. Northern Power currently produces only a 100 KW turbine, but is in final testing 600 KW and 2.2 MW units. To anticipate long lead times in procuring parts, it may be prudent to keep any recommended spare parts on hand. Types and quantities vary with each wind turbine manufacturer. However, with any turbine chosen, O&M training and an on-hand spare parts inventory are both recommended.

Final note: depending on the location of the wind turbine, one could infer that the system could be used as a target reference point by the enemy.

Geothermal (not GSHPs)

Technology description

Geothermal resources capable of producing electricity range from hot springs that emerge at the earth’s surface to hot water and rock several miles deep in the Earth’s crust. Conventional geothermal resources produce electricity at temperatures above 300 °F. Geothermal electricity was a commercial success in Italy in the 1940s, in the United States by 1960, and is now a part of the electricity grid in 24 countries. Advances in 21st-century geothermal power generation technologies make it possible to generate electricity with water temperatures as low as 160 °F. This advance expands the viability of geothermal power generation into broad geographic regions previously thought to have no geothermal potential.

Three types of geothermal power plants operate today: (1) Dry steam plants use geothermal steam directly to turn turbines, (2) Flash steam pulls deep, high-pressure hot water into lower-pressure tanks and uses the resulting flashed steam to drive turbines, (3) Binary-cycle plants pass moderately hot geothermal water by a secondary fluid with a much lower boiling point than water, causing the secondary fluid to flash to vapor and drive a turbine. World-wide geothermal production of electricity via one of these three methods will exceed 70,000 GWh in 2010.

The potential of geothermal energy in Afghanistan is enormous, due to its geologic setting. Geothermal systems in Afghanistan are not limited to those with hot springs indicators at the surface. Many volcanic, magmatic, and fault-line systems represent widespread hidden potential for geothermal energy sources at moderate depths (Saba et al. 2004).

Existing usage

Based on previous research, Afghanistan has the potential for geothermal power plants. There are many hot springs throughout Afghanistan, especially near the Hindu Kush Mountain Range. Based on the tectonics, the fault lines in Afghanistan have the potential to produce geothermal heat. Hot springs around micro plates in the region are indicators of geothermal energy.

The US military has invested in domestic geothermal energy, most notably at the Rocky Mountain Oil Field Test Center, the Naval Air Station at Fallon, and Coso Geothermal Field at China Lake, CA. The Coso plant, which has been operation for over 15 yrs, hosts four power plants and nine 30 MW turbine generators, and can produce 273MW of electricity at its peak.

The path of the Coso project, however, was not expedient. The project was conceived in the early 1960s, but full-scale engineering and scientific investigation was delayed to 1977, when 17 heat flow holes were drilled. The site had its first working geothermal plant in 1987, and was fully operational in 1990. This is a span of almost 30 yrs. While the overall project has been a huge success, the timeline was lengthened by technology development and availability of inexpensive petroleum. Projects undertaken in the 21st century will benefit from the lessons learned in the developmental

stages of geothermal electricity, and will be propelled forward by pressing need in areas where oil is unavailable or prohibitively expensive.

Viability for ANSU

Determining the immediate viability of geothermal electricity for the ANSU will require a significant amount of research, testing, and exploration. Geologic indicators near the ANSU site suggest geothermal potential (Saba et al. 2004). It is likely that Afghanistan holds adequate geothermal resources to power the ANSU, as well as a significant portion of the western half of the country. Return on Investment (ROI) is relatively quick for a conventional or low-temperature geothermal power plant, usually in the range of 5 to 7 yrs. The ROI for a complete 20MW plant installation, from exploration to deep test wells to completion of the power plant would likely be less than 10 yrs and would provide constant power for generations to come, independent of foreign input.

As noted above, it will require extensive research, testing, and exploration to locate a geothermal plant on the ANSU site. A better alternative is to work with the Afghan Ministry of Energy and Water to assess sites in the Kabul region. This plant would provide power to the city and, perhaps, an electrical feeder to the ANSU from the geothermal site.

Solution

Geologic/geothermal site characterization of the ANSU and surrounding Kabul area must be completed to determine the geothermal potential. Through regional cooperation, contributions of expertise provided by NMAA instructors, and funding in conjunction with other aid organizations, a facility for generating geothermal electricity could be located at some distance from the ANSU if necessary. While the timeline would still be close to a decade, the chance for success increases if exploration and well drilling occur near already known geothermal indicators. This would overcome the limitations of locating a generating facility within the ANSU complex.

Savings

Fiscal savings from a geothermal power plant could be realized in just a few years. Most of the costs of a geothermal power plant are “up front,” for

geologic and geophysical surveys and drilling, which is then followed by analysis of the drilling information. Only after this is complete and the results prove satisfactory could the plant be built. However, the cost savings after the plant has paid for itself would greatly exceed those of a solar or wind farm. Geothermal power costs approximately $0.03 to $0.06 per kWh based on O&M costs. A gallon of diesel provides roughly 12.7 kWh/gal based on 62.5 percent operating efficiency. Thus, it takes $0.76 of geothermal power to produce the same power as a gallon of diesel. Based on the assumption that the FBCF is $4.40/gal geothermal power offers a savings of 82.7 percent; at an FBCF of $10/gal geothermal savings rise to 92.4 percent; and at an FBCF of $20/gal, geothermal yield savings of 96.2 percent.

Investment

Currently the cost for a geothermal power plant to be built in the United States is about $2500–$5000 per installed kW. (The price range is a function of the size of the plant.) Economies of scale reduce the installation cost as output increases. For a 20MW geothermal power plant, the cost is anywhere from $50–$100 million, and operation and maintenance cost of $0.01–$0.03 per kWh. Although initial costs are high, the facility would be easy to manage, and would provide clean, cheap, renewable energy for decades to come. A 20MW plant could be operated by 10 to 15 trained workers after the technology was turned over to local administration.

To provide a more realistic cost analysis for building a geothermal plant in Afghanistan, additional concerns for transport of materials, security, and bureaucracy must be considered. A cost multiplier of 3 to the project is a “best guess.” Because of the dynamic nature of Afghanistan’s security, this number is only an approximation. However, these regional factors raise the cost of the plant per installed KW to $7500 to $15,000, putting the cost of a 20MW geothermal power plant at roughly $150–$300 million with the O&M costs at roughly $0.03–$0.06 per kWh.

Summary of advantages

- Geothermal resources can provide Afghanistan with a domestic source of energy that is clean, renewable, and independent of the carbon-fuel industry. Once developed, geothermal power reduces dependence on foreign energy sources proportionately.

- Use of geothermal energy can create permanent full-time jobs for Afghans, while decreasing the trade deficits and saving valuable foreign reserves of the country.
- With very low pollutant byproducts, geothermal energy is the most environmentally clean sustainable renewable energy source that could be exploited in Afghanistan.
- Geothermal energy provides a base-load power source, independent of weather conditions.
- Afghanistan has limited acreage of land suitable for industrial development. Geothermal power has the smallest footprint of any energy source per GW of power, with an average requirement of only 400 $m^{2/}$GW.
- Development of geothermal resources in Afghanistan will strengthen the technological and research capability of the country and open new areas of international technical cooperation (Saba et al. 2004).

Simple payback

Table 11 lists the simple payback timeline for the proposed 20MW geothermal power plant based on fuel costs and plant costs. To calculate the simple payback, gallons of fuel consumed per year were determined based on the $45 million fuel budget. Then, using the cost for geothermal power of $0.76/gal, the fuel cost in terms of geothermal power is determined. Next, the difference between the cost of geothermal power and the cost of diesel yields the savings. Finally, to determine the simple payback in years, the cost of the power plant is divided by the savings.

SIR

An assumed interest rate of 4 percent was used to calculate the savings to investment ratio. Table 15 lists average annual savings on fuel, based to present value, for a timeline of 5, 10, 15, 20, 25, and 50 yrs.

Table 14. Simple payback for the geothermal estimates.

Simple payback (yrs)	$4.40/gal	$10/gal	$20/gal
$150M Plant	5.24	1.75	0.80
$300M Plant	10.48	3.51	1.60

Table 15. SIR for the geothermal estimates.

SIR (yrs)	$150M plant cost			$300M plant cost		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.85	2.54	5.55	0.42	1.27	2.78
10	1.55	4.62	10.11	0.77	2.31	5.06
15	2.12	6.34	13.86	1.06	3.17	6.93
20	2.59	7.75	16.95	1.30	3.87	8.47
25	2.98	8.90	19.48	1.49	4.45	9.74
50	4.10	12.24	26.79	2.05	6.12	13.39

Long-term considerations (O&M, complexities, replacement parts, labor skill)

The estimated costs to verify a geothermal source at ANSU would be in the order of $9M to take the geochemical data and drill the test wells, based on the multiplier of three. If a source were found, it would have the potential to power much more than ANSU. With the high costs and the potential to power much of Kabul, it would be best to leave this exploration cost to the Afghans.

GSHPs

Technology description

GSHPs make use of the constant temperatures in the upper layers of the Earth's surface. Here the temperature consistently fluctuates between 50–60 °F. In the summer, the heat pump removes heat from the air into the heat exchanger, using the earth as a heat sink. In the winter, the process is reversed and the heat pump removes heat from the exchanger and pumps it into the delivery system. This method uses the ground as a heat source. By using ground-source heat, much less energy is needed to heat buildings. The result is saving energy and money. There are three main parts to a GSHP: the ground heat exchanger, the heat pump unit, and the ductwork. Heat pumps can be installed in three different ways. The heat exchanges can be installed vertically into the ground roughly 75–200 ft deep. This is best used to reduce the footprint of the heat pumps. They can also be installed horizontally, in a trench beneath the frost line. Excavation costs for horizontal drilling are roughly half those of vertical excavation. The last method is to sink the heat exchanger loops in a lake or pond; this method eliminates excavation costs, but requires a body of water.

Studies show that approximately 70 percent of the energy used in a geothermal heat pump system is renewable energy from the ground. The earth's constant temperature is what makes GSHPs one of the most efficient, comfortable, and quiet heating and cooling technologies available today. While they may be more costly to install initially than regular heat pumps, USEPA estimates show that they can produce markedly lower (30 to 40 percent) energy bills. (The USEPA now includes GSHPs in the types of products rated in the Energy Star® program.) Because they are mechanically simple, and because the system's external parts are below ground and protected from the weather, maintenance costs are often lower as well.

Existing use

There is over 12 GW of thermal capacity worldwide stemming from GSHPs. In the United States, alone 7485 MW of thermal capacity is being produced. Moreover, many homes and even the Army's Residential Community Initiative (RCI) contractors are installing GSHPs as a system of choice, both at Fort Polk, LA, and Fort Knox, KY. GSHPs are primarily installed in the United States and Europe, although China is also attempting to leverage this technology in more of its projects. The GSHP is a proven and mature renewable energy technology.

Installing GSHPs will eliminate the need for individual heating and cooling devices for each office, increase the aesthetics of the building by eliminating individual mini-split units, reduce heating and cooling costs, and maximize the effectiveness of the technology.

Viability for ANSU

The assessment of ANSU energy needs reveals a minimal cooling requirement. This is solely based on the CSTC-A command directive that states that only a limited number of facilities will receive HVAC, specifically, senior command HQs and living quarters, medical facilities, and information technology (IT) rooms. Because GSHPs can provide both heating and cooling to a building, installing a GSHP system may not be the most cost effective means of lowering heating expenses alone. For such a system to be economically viable, the building must be both heated and cooled. Current plans designate only two buildings that match this description, the ANSU Headquarters Building (where there numerous IT rooms and also where high ranking officers will work), and the Medical Clinic.

Solution

The two places where GSHP technology is a potentially viable option are the ANSU Headquarters (Bldg 301) and the Medical Center (Bldg 125). None of the other buildings will require cooling that reduces the functionality of the GSHP system. Should the scope of the project shift to require a larger centralized cooling load, GSHP technology would be an ideal solution to reduce energy costs. Table 16 lists requirements for a GSHP for the two buildings assumed to receive both heating and cooling.

To meet the estimated cooling load of 294 tons, a water-cooled centrifugal chiller is used as the base system to compare against the GSHP system. Typical energy performance of a high efficiency chiller is:

> 0.56 kW/ton (full load) and 0.47 kW/ton (IPLV) (USDOE 2004).

The Energy Star eligible GSHP must have an energy performance of 16.1 EER or 3.5 COP for water-to-air GSHP (USDOE 2011). The conversion of Energy Efficiency Ratio (EER) or Coefficient of Performance (COP) in kW/ton yields the energy efficiency of GSHP of:

> 1.0 kW/ton. [Note the conversion factor is COP = 3.517/ (kW/ton)].

Therefore, the base case with a conventional water-cooled centrifugal chiller is almost twice more energy efficient than a GSHP system to provide cooling to the ANSU HQ building.

Table 16. GSHP requirements for ANSU facilities receiving heating and cooling.

Bldg	Area (sq ft)	Cooling Required (tons) @ 300 sq ft/ton	Footprint (acres)	Capital Cost in the United States @ $5400/ton	Annual O&M Cost in the United States @ $0.18/sq ft
125: Medical Center	11,087	37	0.25	$200,000	$20,000
301: ANSU HQs	88,265	294	1.0	$1,587,600	$15,900

According to the California Energy Commission (2011):

> [A]s a rule of thumb, a geothermal heat pump system costs about $2500 per ton of capacity. ... You will have to, however, add the cost of drilling to this total amount. The final cost will depend on whether your system will drill vertically deep underground or will put the loops in a horizontal fashion a shorter distance below ground. The cost of drilling can run anywhere from $10,000 to $30,000,

or more depending on the terrain and other local factors. [This drilling cost is based on a 3-ton GSHP residential unit.]

Therefore, for ANSU HQ's, a water-cooled centrifugal chiller is recommended since a GSHP is less efficient in energy and dollars for space cooling. For the Medical Clinic with a 37-ton cooling load, the economy-of-scale of the ground-loop infrastructure favors a packaged air-cooled AC system on the first-cost and life-cycle cost basis.

GSHP is therefore not recommended for the ANSU project due to the limited cooling requirement in the entire complex.

Long-term considerations (O&M, complexities, replacement parts, labor skill)

GSHP technology is mature and reliable. Since heat pump equipment is not exposed to the outdoor elements, the units require less maintenance than outdoor air units. Following the manufacturer's recommended maintenance program will keep these units operating reliably for years.

Conversely, one major risk factor to consider is that, if a pipe failed, it would require the system to remain down for a considerable period of time. The repair would be expensive, require skilled craftsman, and necessitate on-hand specialized tools and parts — all of which may be resources in short supply.

Waste-to-energy (includes biomass)

Technology description

WTE is the process of creating usable energy in the form of heat or electricity through a combustion process. Incineration is the primary means to produce recovery energy, though other non-incineration methods are used as well. The goal of WTE technologies is twofold. First, the energy from the waste can be reused in other processes, including powering generators, engines, and turbines. Secondly, these devices reduce the volume of waste by as much as 96 percent. By burning the waste, it is possible to heat water to its boiling point to power steam generators. Using scrubbers and other air pollution control devices, it is possible to generate "cleaner" emissions from an incinerator than from a typical residential fireplace.

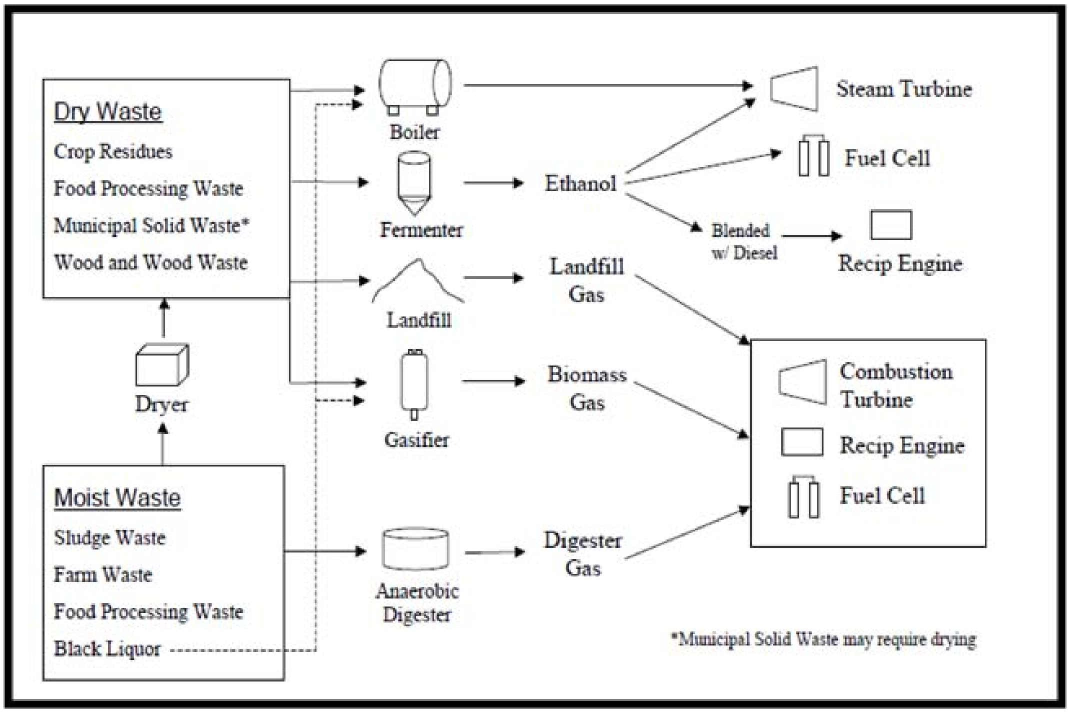
Other WTE processes that do not use direct combustion can actually produce more energy than is possible by simple incineration. Other thermal technologies include:

1. Gasification, which produces a combustible synthetic gas (syngas) of carbon monoxide and hydrogen gas
2. Pyrolysis, which produces a combustible tar and bio-oil.
3. Other non-thermal approaches that include anaerobic digestion and fermentation to produce methane and hydrogen, respectively.

For this study, biomass will be considered a WTE feedstock. This is due to limited amounts of available biomass material for a separate and distinct biomass plant. Below is a short discussion on energy from biomass. It is not analyzed in this study as an alternative form of energy due to the limited amount of biomass available.

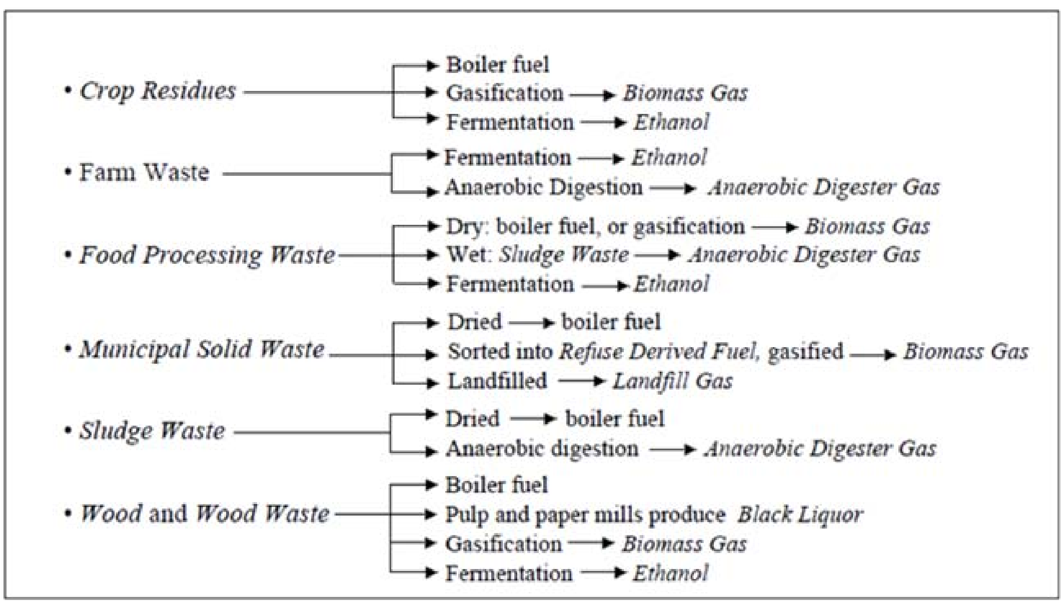
Unlike other renewable energy sources, biomass can be converted directly into the liquid fuel, the most popular being biodiesel and ethanol. Ethanol is made by fermenting biomass high in carbohydrates. It can also be produced through gasification. Biodiesel is made by combining alcohol with vegetable oil or recycled cooking grease. Biodiesel, because of its popularity, is covered in a separate section of this report.

Biomass energy is harvested in five different ways: (1) direct-firing, (2) co-firing, (3) gasification, (4) pyrolysis, and (5) anaerobic digestion. Co-firing is the mixing of biomass with fossil and waste fuels in conventional power plants. Gasification converts biomass into a syngas of hydrogen and carbon monoxide through an oxygen starved process. Removing all oxygen from the process is called pyrolysis. Anaerobic digestion produces a methane gas and can transform wastes into compost. Figure 6 shows a flowchart of biomass fuels. Figure 7 shows a variety of ways biomass can be used to produce energy. The following sections describe several WTE processes.



(Source: Resource Dynamics Corporation. 2004. Distributed Energy Program Report: Combined Heat and Power Market Potential for Opportunity Fuels. USDOE, Energy Efficiency and Renewable Energy, p 2-2, http://www1.eere.energy.gov/industry/distributedenergy/pdfs/chp_opportunityfuels.pdf.)

Figure 6. Flowchart of biomass fuels.



(Source: Resource Dynamics Corporation. 2004. Distributed Energy Program Report: Combined Heat and Power Market Potential for Opportunity Fuels. USDOE, Energy Efficiency and Renewable Energy, p 2-4, http://www1.eere.energy.gov/industry/distributedenergy/pdfs/chp_opportunityfuels.pdf.)

Figure 7. Biomass fuels.

Gasification

Gasification is the process that converts carbon-based materials, such as biomass waste, into carbon monoxide and hydrogen gas through a high temperature oxygen controlled environment. The technique was developed in the 19th century and was widely applied in Europe during World War II due to the shortage of gasoline. Small gasifiers were installed on top of trucks and ships and the syngas was channeled into the engine. The gasification process itself is broken down into four distinct phases: (1) drying, (2) pyrolysis, (3) combustion, and (4) reduction. By separating these four phases it is possible to produce a syngas, which can then be used as a fuel.

In the first phase, the drying process seeks to remove water content from the biomass or waste, creating steam that will be used later in the reduction stage and allowing the following stages to be more efficient. In the pyrolysis phase, the waste is heated in an oxygen starved environment that results in the production of charcoal and tars. The combustion process combines oxygen with the charcoal and tars to produce CO_2 and CO. The limited amount of oxygen let into the system allows some of the material to be burned to produce carbon monoxide and energy. This drives the follow-on reaction in the reduction phase. The reduction stage of the gasification process produces H_2 and CO gases after the charcoal reacts with steam. The reduction phase occurs in temperatures between 700–900 °C using the reduction reaction:

$$C + H_2O \rightarrow H_2 + CO$$

The gasification process is more efficient that incineration because a syngas is directly produced, rather than merely generating steam to drive a turbine. This syngas can continue to be refined into other synthetic fuels instead of electricity. Additionally, gasification neither emits nor traps greenhouse gases.

Anaerobic digestion

Anaerobic digestion is the use of micro-organisms to break down biodegradable material in an oxygen starved environment. Almost any biodegradable material can be digested, with the exception of woody wastes due to their high content of lignin (although use of lignin consuming anaerobes can mitigate this limitation). This process is widely used in wastewater

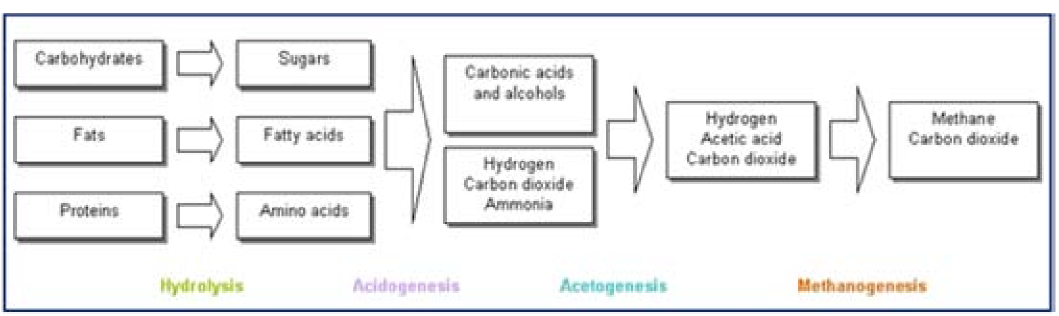
treatment. The anaerobic digestion process produces a methane and carbon dioxide rich biogas that can replace fossil fuels.

Figure 8 shows the stages in the anaerobic digestion process. The first stage in the process starts with bacterial hydrolysis of the material. This breaks down insoluble organic polymers to the point where bacteria can act. Certain bacteria convert the sugars and amino acids found in the materials into carbon dioxide, hydrogen, ammonia, and other organic acids. Other bacteria convert the organic acids into acetic acid and into the other three main gases. Lastly, methanogens convert these acids into methane and carbon dioxide.

The United Nations has identified anaerobic digestion as one of the most useful decentralized sources of energy supply, and one that requires less capital to construct than power plants. Typically, the biogas produced is used to run a gas engine that produces electrical power, and waste heat from the engine is used to heat the digester to the required temperatures.

Incineration

Incineration involves the combustion of organic materials over high temperatures otherwise known as thermal treatment. Incineration of these organic materials converts waste into flue gases, particulates, and heat, which can then be used to produce electrical power. On a large scale, an incinerator is a giant furnace that burns waste. Types of incinerators include: (1) moving grate, (2) fixed grate, (3) rotary-kiln, (4) burn pile, and (5) fluidized bed. A burn pile or moving grate will best serve the ANSU site's purposes. Incinerators reduce the weight of the original mass by 80–85 percent and the volume by 95–96 percent.



Source: http://en.wikipedia.org/wiki/Anaerobic_digestion

Figure 8. Stages in the anaerobic digestion process.

The private burn pile is the simplest form of an incinerator. It is easily constructed and most often used at Forward Operating Bases (FOBs). The private burn pile consists of a mound of combustible materials piled on bare ground and eventually set on fire. The disadvantage of using burn piles is that they are placed out in the open and can produce uncontrollable fires. (A strong gust of wind can easily move the flames to other areas of the site.) Additionally burn piles emit unfiltered smoke and particulate matter emitted that may cause a health hazard for surrounding areas.

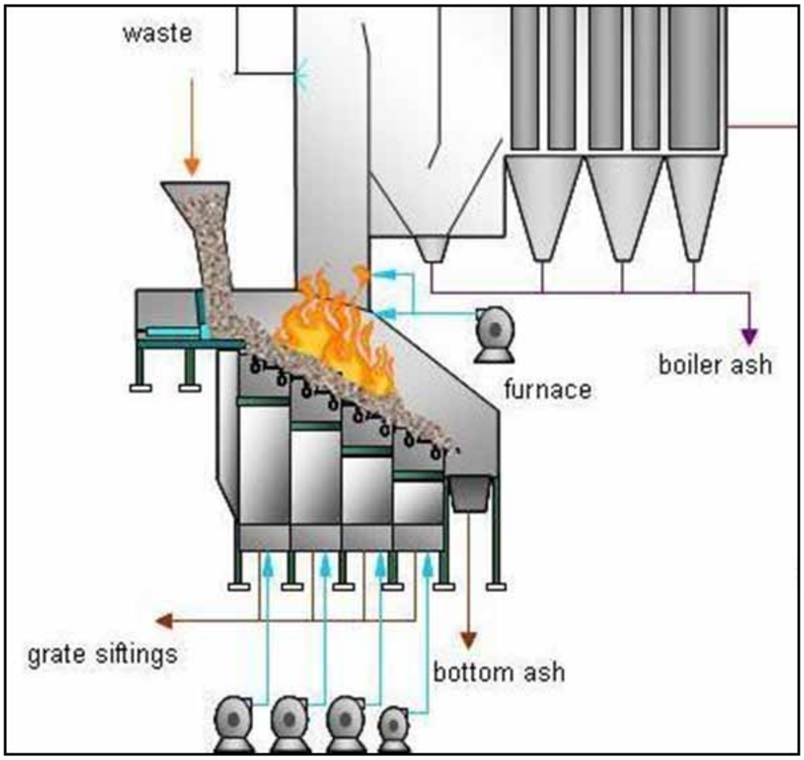
One typical type of incineration plant is the "moving grate incinerator." The moving grate (Figure 9) moves the waste material through the combustion chamber to allow for a more efficient and effective combustion. Combustion air is supplied from both above and below the grate, cooling the grate and introducing turbulence, which facilitates complete combustion. The turbulence ensures a surplus of oxygen for a better combustion mix.

The heat from the incinerator can be used to produce steam, which can drive a turbine that generates electricity. The net energy produced per ton is about 0.6 MWh of electricity. Figure 10 schematically shows a typical WTE incineration plant.

Thermal depolymerization

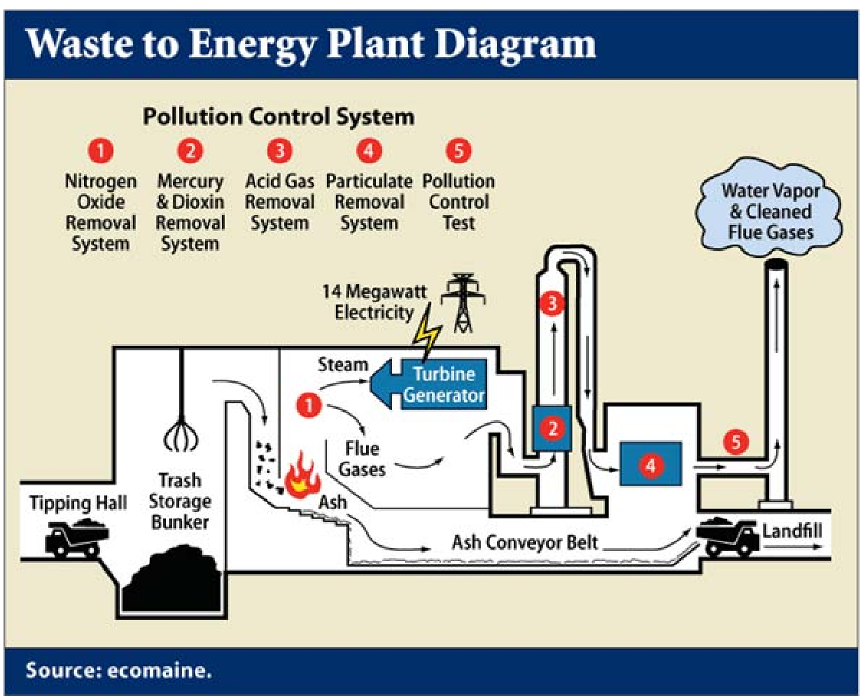
Thermal Depolymerization (TDP) is the process of using hydropyrolysis to reduce complex organic materials into light crude oil. The process (Figure 11) is very similar to the geological process that produces fossil fuels.

The initial phase of TDP begins with grinding waste material into small chunks, which are then mixed with water. The mixture is then fed into a pressure chamber where it is heated up to 250 °C at constant volume. After it has been heated for 15 minutes, it is depressurized to boil off the water that is left. The result is a mix of crude hydrocarbons and solid minerals. The hydrocarbons are then sent to a second chamber where they are heated to 500 °C, which further breaks down the hydrocarbon chains. Finally the hydrocarbons are sorted by fraction distillation. The hot fluid moves into distillation tanks, where it cools and condenses. The organic materials and water separate. The water sinks to the bottom. A fuel gas is taken off the top, leaving a crude oil similar to a mix of diesel fuel and gasoline. The crude oil is then stored in a tank for later use.



Source: http://www.winderickx.pl/en/msw_municipal_waste_incinerators.php

Figure 9. Incineration grate.



Source: Window on State Government, Texas Comptroller of Public Accounts, http://www.window.state.tx.us/specialrpt/energy/renewable/municipal.php, adapted from ecomaine website, http://www.ecomaine.org/electricgen/index.shtm

Figure 10. Typical WTE incineration plant.

(Source: Changing World Technologies, Inc., 2010, http://www.changingworldtech.com/what/index.asp.)

Figure 11. TDP process.

Changing World Technologies (CWT) currently uses TDP to run its plants. A CWT analysis has classified various waste products in terms of the various amounts of fuel they can produce, e.g., 100 lb of plastic bottles will yield 70 lb of oil, and 100 lb of old tires can yield 44 lb of gas.

Viability for ANSU

Waste disposal and removal are important needs for the ANSU complex. The use of a WTE technology would eliminate the need for trash disposal on site and greatly reduce the volume of waste to be removed (by 90 percent). This would decrease the number of trucks travelling into and out of the camp, and reduce the security risks from improvised explosive device (IED) attacks. If ANSU is to use a WTE technology fueled by biomass alone, a primary consideration is the location of the ANSU complex relative to potential biomass feedstocks. An exceptionally large volume of crop residue and onsite- generated waste would be required to make a WTE plant a viable option at the ANSU complex.

The farm waste from the crop farming and (modest amount of) livestock farming in the vicinity of the ANSU complex does not have the potential to produce much energy for the overall site. Still, it may be possible to supplement local farm waste other with sources of biomass as a boiler fuel. Food waste produced on site is not a likely candidate. Little food processing will be done onsite, as most of the processing is done by the packaging companies before the food is delivered to the site. Moreover, the use of food processing waste as biomass feedstock works best in a co-fired plant because of the variety in moisture content and energy potential from

different food wastes. It may be possible to use sludge waste as biomass feedstock (discussed in the WTE section of this report).

Wood waste may also be introduced as a WTE supplement. However, there are few local sources for wood waste, e.g., there is no paper mill nearby (nor is one anticipated), so “black liquor” is not an option for the site. Wood waste will likely come in the form of pallets and other wood dunnage from the military training operations at the ANSU complex that can then be incinerated.

Considering that no single biomass feedstock may be available to the ANSU complex, the best option is likely to combine as many types of waste material and biomass as possible. The only method that would accommodate the combination of diverse biomass feedstocks that may be available on-site is the boiler steam method or incineration method. Incineration can produce energy and a (heat) waste steam that can be used for building space heating or water heating.

Two other WTE methods worthy of consideration are gasification and anaerobic digestion. Gasification offers the potential to produce a stored energy source from creation of syngas. There are currently commercial options for gasifiers available that could manage the waste stream effectively. Anaerobic digestion could be used to produce enough heat to maintain the peak digestion process, with any additional biogas being used to provide electricity to the complex. (Anaerobic digestion is discussed separately.)

Solution

This analysis is based on the 90,500 m^2 of heated floor area, a heating load of 100 W/m^2, and 30 percent of the domestic hot water heating base demand coming from biomass heating, assuming that the rest will be covered by solar domestic hot water heating. Based on its population and size, an expected rate of trash production for the ANSU complex is 5840 tons/yr (16 tons/day) (Table 17). Considering that estimated organic content for Kabul’s MSW is estimated at 55–80 percent, it is feasible to use a combination of mixed solid waste, agricultural waste, and biomass material in a single incineration plant. Based on this analysis, it is possible to heat the ANSU complex with biomass alone.

Table 17. Analysis summary based on incineration plant size.

Plant Size (MW)	Expected Daily Energy Production (MWh)	Daily Required Waste (tpd)*	Daily Added Biomass Required (tpd) †	Amount of Steam Generated for Heat (lbs/hr)	Amount of Water Required (gpd)	Footprint (acres)	Capital Cost ($M)	Annual O&M Cost ($M)
0.4	9.6	16	0	1,140	3,285	0.5	3.0	0.43
2.0	48	80	64	5,715	16,400	1.25	9.6	2.15
5.0	120	200	184	14,300	41,000	2.5	23	5.4
12.6	302	600	584	36,000	103,000	5	55	13.5
20.4	490	900	884	50,000	168,000	10	85	22

* Assumes 8500 Btu/lb

† Total required minus trash created.

Anaerobic digestion may potentially be used to provide thermal energy for the wastewater treatment plant. Even though the anaerobic digestion process requires a certain temperature range to continue, the process itself would eliminate heating costs during the colder months because the biogas it produces could be used to run a heater.

The most efficient way to produce energy from waste would be either by an incineration or gasification system. Of the two, incineration would be the easier system to operate because all the waste (with some exceptions) could be run through the system without sorting and separating. Due to environmental concerns, incineration will require additional treatments for stack exhaust gases produced; conventional air pollution control devices already used at incineration plants can provide the needed treatments.

An incineration system could also be incorporated into either a heating-only, or a “co-generation” incineration plant. The greatest drawback of the heating-only option is that it would require a district heating system complete with underground piping and a central plant. Building a “co-generation” incineration plant could serve two purposes: electrical energy production and building/water heating. Using the waste heat from the steam could be much more efficient than the current plan of electric resistance heating, and the power production from a combination of municipal solid waste, wood waste, and crops residues can be used to produce steam to drive a turbine. However, availability of water is a major issue in Afghanistan. A cogeneration plant is unfeasible at the ANSU site since cogeneration technology requires a constant supply of treated water, and a dedicated source of water cannot be identified or guaranteed.

Therefore, a 0.4-MW biomass incineration plant is feasible and recommended, using the residual heat generated to heat domestic hot water. This sized plant does not require the delivery of waste materials from outside the site. However, if a larger plant is considered, then waste materials will need to be delivered into the complex.

Savings (energy and ancillary)

WTE incineration

WTE incineration reduces the need for hauling almost all of the generated trash offsite. This equates to 16 tons of waste per day, on average. At an estimated cost of $300/ton for removal from the site, the savings from switching to incineration is $1.75 million/yr. Ash from the incinerator will still need to be hauled off or stored on site, but the volume of ash is at least 90 percent less than the volume of waste on the untreated waste. Additionally, using the municipal solid waste internal energy of 4500 BTU/lb and an efficiency of 40 percent, there is the potential to produce a diesel fuel equivalent of 152,267 gal/yr for a 0.4-MW plant. Using the FBCF of $4.40, the process could achieve an annual savings of about $670,000/yr. If the plant were sized to handle more than just the waste of the complex, a tipping fee could be charged per ton of waste hauled into the site.

Anaerobic digestion

A typical wastewater treatment plant uses 508 to 2428 kWh (PG&E 2001) for every million gallons treated. For economies of scale, assume for purposes of this study 2.5 kWh for every 1000 gal. If the total water usage were 140,000 gal/day, then the water treatment energy consumption would be 350 kWh/day, which equates to an annual water treatment energy consumption of 127,750 kWh/yr. The annual diesel fuel savings would then be 127,750 kWh/yr divided by 12.7 kWh/gal, or 10,059 gal/yr. Using the FBCF of $4.40, the process could achieve an annual diesel fuel cost savings of $44,260.

Investment

WTE incineration

Table 18 lists the estimated investment costs for two WTE plants.

Table 18. Waste-to-energy incineration investment costs.

Item	Cost	
	0.4-MWth Plant	2-MWth Plant
Incineration plant	$3,000,000	$9,600,000
O&M costs	$309,600	$1,548,000
Fly ash removal	$120,000	$600,000
Plant footprint	0.5 acre	1.5 acre

Anaerobic digestion

Table 19 lists the estimated investment costs for an anaerobic digester at 100 tons/yr (140,000 gal/yr).

Table 19. Anaerobic digester investment costs.

100 ton/yr Anaerobic Digester	Total cost
Capital cost: $6/gal	$840,000
O&M cost: $90/ton	$9000

Simple payback

WTE incineration

Table 20 lists simple payback for WTE incineration plants.

Table 20. Simple payback for WTE incineration plants.

Simple payback in years	$4.4/gal	$10/gal	$20/gal
$9.6M plant	2.87	0.89	0.36
$3M plant	4.48	1.38	0.56

Anaerobic digestion

Table 21 lists simple payback for anaerobic digestion.

Table 21. Simple payback anaerobic digestion.

Simple payback (yrs)	$4/gal	$10/gal	$20/gal
$840k plant	23.82	9.17	4.37
$900k plant	25.52	9.83	4.68

SIR

WTE incineration

Table 22 lists SIR for WTE incineration plants.

Table 22. SIR for WTE incineration plants.

Waste to Energy SIR (yrs)	2 MWth Plant Costing $9.6M			0.4 MWth Plant Costing $3.0M		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	1.55	5.03	12.40	0.99	3.22	7.94
10	2.83	9.16	22.60	1.81	5.86	14.46
15	3.88	12.55	30.98	2.48	8.03	19.82
20	4.74	15.34	37.86	3.04	9.82	24.23
25	5.45	17.64	43.52	3.49	11.29	27.85
50	7.50	24.25	59.85	4.80	15.52	38.30

Anaerobic digestion

Table 23 list SIR for anaerobic digestion.

Table 23. SIR for anaerobic digestion.

AD SIR (yrs)	$840k plant cost		
	$4.4/gal	$10/gal	$20/gal
5	0.19	0.49	1.02
10	0.34	0.88	1.86
15	0.47	1.21	2.54
20	0.57	1.48	3.11
25	0.66	1.70	3.57
50	0.90	2.34	4.91

Long-term considerations (O&M, complexities, replacement parts, labor skill)

Costs

O&M costs for WTE plants are normally higher than those for plants that burn fossil fuels. The typical annual O&M cost for a plant is roughly 15 percent of the total cost of the plant. Also, because of the relatively smaller size of WTE plants, their O&M costs will amount to a larger percentage of overall annual costs compared to a larger plant. Also, replacement parts for WTE plants are expected to be difficult to procure due to fact that the (boiler and steam turbine generator) technology is not common in Afghanistan.

Labor

The issue of availability of skilled labor is not as prominent for WTE technologies as it would be for other, more involved technologies. Nevertheless, a WTE plant will require a dedicated staff. Also, to increase the success of this project over the long term, it may be best to assess the size of

the plant to meet the needs of the ANSU complex, and then to oversize the plant to capitalize on the economies of scale, and to enable the plant to sell additional power to the Kabul grid.

District heating

ANSU may also wish to consider changing the building heating systems from the current decentralized condition to a centralized heating system, complete with underground piping and auxiliary systems to take full advantage of this technology application.

WTE hauling and storage, and ash disposal

Another consideration is the amount of additional biomass required daily to keep the plant operational. This material would have to be transported into the complex every day via trucks. Due to the expected large amount of daily traffic through main gate, it is recommended to have a “service entrance” just to haul in the biomass and other “unsightly” materials, and to haul out the ash. Additionally, it is recommended to maintain at least 7 days minimum of biomass material on hand in a covered facility. A 3500 sq ft facility is needed to keep this amount of material. Unless stored, ash hauling and disposal would be required daily.

Pollution

Recent research has identified another biospheric process that has instantaneous and longer term effects on the production of atmospheric gases, biomass burning. The extent of biomass burning has increased significantly over the past 100 yrs because of human activities. In fact, such burning is much more frequent and widespread than was previously believed. Biomass burning is now recognized as a significant global source of emissions, contributing as much as 40 percent of gross carbon dioxide and 38 percent of tropospheric ozone.

The incineration process can result in three potential sources of exposure: (1) via emissions to the atmosphere, (2) via solid ash residues, and (3) via cooling water. Provided that solid ash residues and cool water are handled and disposed of appropriately, atmospheric emissions remain the only significant route of exposure to people.

Air pollutants such as dioxins that the incineration process can produce are very persistent in nature. Such pollutants settle on the surrounding vegetation, soil, and water bodies. Short-term exposure of humans to high levels of dioxin can lead to severe respiratory problems; long-term exposure results in impairment of the immune system, nervous system, reproductive functions, and endocrine systems. To capture these harmful pollutants, properly-sized and designed air pollution emission controls are highly recommended for any WTE plant.

Fuel cells

Technology description

A fuel cell is an electrochemical power generator with the potential to attain very high electrical efficiencies with minimal polluting emissions (Figure 12). The fuel cell uses an electrolyte to produce a reaction between a fuel and an oxidant, which generates electricity. What differentiates fuel cells from batteries is the fact that fuel cells consume reactant from an external source. The most common reactant is hydrogen. Unfortunately, usable hydrogen ions are not naturally occurring and must be processed from another compound. There are many different ways to produce hydrogen gas, but all require processing a fuel. The primary method of hydrogen production is currently steam reforming. This process can produce hydrogen from natural gas (with 80 percent efficiency); propane, methane, and anaerobic digester gas are also commonly used fuel sources. Fuel cells also produce heat as a by-product, which can be used for cogeneration of hot water or steam.

Existing usage

Currently, fuel cells are commercially available although widespread usage is not currently viable. Fuel cells have been installed in some CONUS installations, primarily as pilot projects for additional research. Industrial-sized fuel cells are commercially available in the 200–300 kW power range, but can be stacked together for larger power requirements. Groups ranging in sizes from 1–5 MW would be feasible.

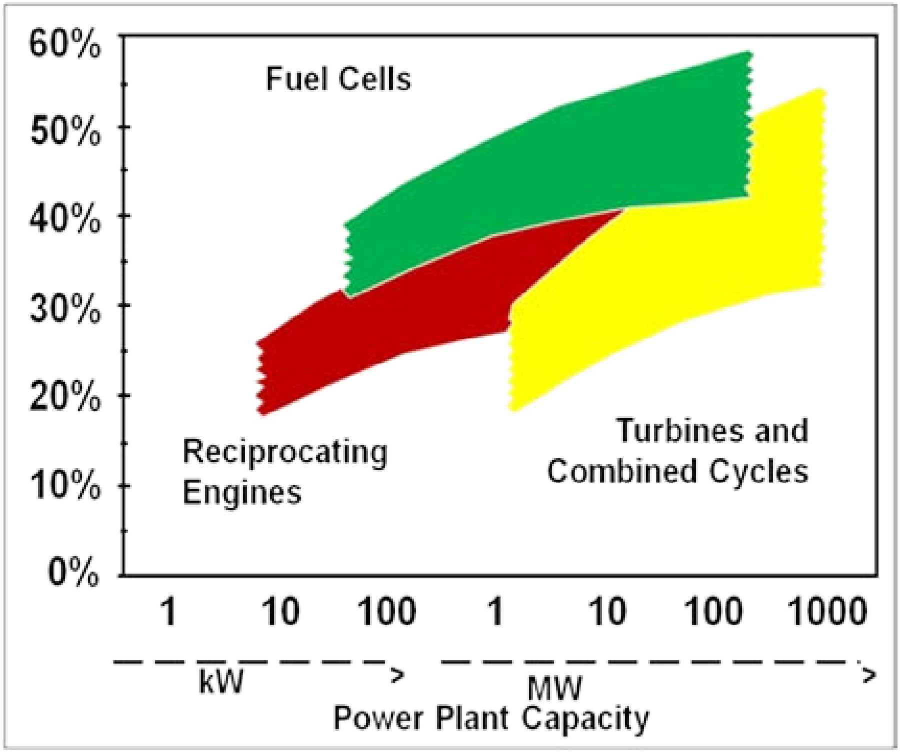


Figure 12. Electrical generating capacity.

Viability for ANSU

Unless a consistent propane, natural gas, or methane fuel stream is identified onsite, the fuel cell's requirement for a continuous fuel source makes the technology unviable for ANSU. The need for a continuous stream of fuel would only shift the dependence from combustion generators to this new fuel, which does not solve the problem. There is currently research being done to reform JP-8 fuel ("Jet propellant 8," a kerosene-based fuel) into a usable energy source for fuel cells. If this option does become available, the use of fuel cells would be nearly twice as efficient as a traditional generator. However, at this time, fuel cells do not provide an energy reduction solution for the ANSU complex. Finally, fuel cells are a sophisticated technology that requires an expert level of knowledge. For this reason, identifying and training O&M personnel for long-term fuel cell maintenance in Afghanistan may be problematic.

Solution

For fuel cells to be a successful alternative source of energy for the ANSU complex, a suitable fuel source must be identified onsite (e.g., a break-

through in reforming JP-8 fuel for use in fuel cells, or some other energy source that can be used to run the fuel cells). Currently, diesel generators have a longer track record, and are easier to set up, operate, and maintain — so they are presently a more attractive option than fuel cells. The benefits of fuel cells would not be realized at the ANSU complex if they were installed in a widespread application. However, a demonstration fuel cell system may be an option, especially as a senior-level cadet project with NMAA. Table 21 lists fuel cell types and their operating characteristics.

Table 24. Fuel cell types.

Fuel Cell	Electrolyte	Operating Temperature	Electrical Efficiency	Fuel
Alkaline fuel cell (AFC)	Potassium hydroxide (KOH) solution	Rm temp to 90 °C	60–70%	H2, O2
Proton exchange membrane fuel cell (PEMFC)	Proton exchange membrane	Rm temp to 80 °C	40–60%	H2, O2, Air
Direct methanol fuel cell (DMFC)	Proton exchange membrane	Rm temp to 130 °C	20–30%	CH3OH, O2, Air
Phosphoric acid fuel cell (PAFC)	Phosphoric acid	160- 220 °C	55%	Natural gas, bio gas, Air, H2, O2
Molten carbonate fuel cell (MCFC)	Molten mixture of alkali metal carbonates	620-660 °C	65%	Natural gas, bio gas, Air, H2, O2
Solid oxide fuel cell (SOFC)	Oxide ion conducting ceramic	800-1000 °C	60–65%	Natural gas, bio gas, coal gas, Air, H2, O2

Hydroelectric power

Technology description

Conventional hydroelectric power uses two primary components: (1) a hydro-electric turbine that converts the energy in pressurized water to mechanical rotating power, and (2) a generator connected to the turbine that converts the mechanical energy to electric energy. Conventional hydroelectric power is a well-developed technology. If the amount of water flowing in a channel or river is known, and the elevation drop (i.e., the "Head") between the top of the reservoir and the location of the turbine discharge is known, power generation can be accurately predicted.

Similarly, there are a number of manufacturers of hydroelectric power equipment throughout the world. A number of companies manufacture hydroelectric equipment of the size and nature that will be required for the ANSU site. Although there are a number of manufacturers, the quality and efficiency of the equipment they manufacture will vary substantially.

Lastly, the amount of power produced is based on the formula:

Head X Flow Rate X Constant = Power

Appendix B gives a more detailed explanation of the equation. In general, the point here is that increasing the “head” or the flow rate increases the power output of the equipment; decreasing the “head” or flow rate will decrease the power produced.

With the increasing emphasis on “Green Power,” some developmental technologies, referred to as “Kinetic Hydropower,” attempt to use the speed of the flowing water in a river or channel to produce power. No dam is needed to implement this form of power generation.

Existing usage

Information available to this study indicates that no hydropower is currently installed near the ANSU site. The assumed source of the water for power production will be Qargha Lake, which probably provides water for domestic uses, recreation, and irrigation. No other potential sources of hydropower have been identified in the area. Hydropower can be installed at Qargha Lake in a manner so that it does not negatively impact any of the other water uses. However, it is probable that maximized power production will not be achieved without negatively impacting the existing water usage patterns.

Note that the scope of this investigation was to identify the installation of hydro generating capability using existing major infrastructure. The possibility of building a new dam or enlarging an existing dam is beyond the scope of this investigation and is not considered in this report.

Viability for ANSU

Appendix B includes a more detailed and expansive explanation of the Hydropower potential at Qargha Lake.

As indicated above, the two factors that determine the amount of power available from a conventional site are the Head and the Flow Rate. Head information available for this report indicates that Qargha Dam has a maximum head of between 25 and 27 m. It is unknown if the head is at times lower due to possible seasonal variation in the lake level. Flow information for the outflow of Qargha dam was obtained from a US Geological Survey monitored gauging station downstream of the dam. The exact location of the gauging station is unknown, as is how accurately the gauging station reflects the exact outflow from the dam.

There are three identified possibilities for hydropower to support the ANSU facility:

Option 1: A powerhouse at the base of Qargha Dam
Option 2: A powerhouse some 2000 m downstream of Qargha Dam
Option 3: A powerhouse using an existing 12-in. diameter pipe at the ANSU facility.

For Option 1, based on the assumption of a constant 25 m Head at the dam and flow rates as reported from the USGS gauging station, the average output of a Hydropower generation station located at the base of the dam will be 26 kW. Power generation will vary from a high of 190 kW to a low of 4 kW as a function of varying flow rates, but the annualized average output will be 26 kW, resulting in an annual energy generation of 227,760 kWh.

For Option 2, the following observations prompted this consideration: It appears from open source (Google Maps) topographical information that there may be as much as a 100 m drop in elevation from the lake surface at Qargha Lake to a location approximately 2000 m downstream of the dam. If this is the case, then constructing a 2000 m long penstock to take advantage of the possible additional elevation difference will approximately quadruple the power output of the facility. Assuming a 100 m head, and flow rates as recorded at the USGS gauging station, the average output of a Hydropower generation station located 2000 m downstream of the dam

will be 103 kW. Power output will vary from a maximum power output of 760 kW to a minimum of 16 kW, but the annualized average output will be 103 kW, resulting in an annual energy generation of 902,280 kWh.

For Option 3, given the extent of the unknowns, the power output may range from almost zero up to a maximum of 90 kW. Assumptions that impact this range of outputs are listed below. For an optimistic assumed output of 90 kW, the annual energy generation of the powerhouse will be 788,400 kWh.

Kinetic Hydropower, using just the energy of the flowing water, is not a viable alternative for the Qargha facility. The flow rates are too low much of the time, and the energy produced by these flows will be miniscule—estimated average less than 5 kW.

Assumptions

Since fairly reliable information, either open source or previously collected, was available, it was judged that it was not worth the risk to personnel to gather information or data via onsite inspection. As such, a number of assumptions must be verified before proceeding with firm plans to build a hydroelectric power plant as described here.

Among these assumptions for Options 1 and 2 are:

- The surface elevation of Qargha Lake does not have large seasonal variation.
- The Flow Rates used in this report are correct. One of the major uncertainties of this report is the location of the gauging station, and whether it correctly captures the outflow from Qargha Lake.
- A 2000-m penstock can be installed without negatively impacting local irrigation activities or other water uses immediately downstream of the dam.
- That the elevation drop between the surface of Qargha Lake and the end of the 2000-m penstock is approximately 100 m.
- Local topography and geology will accommodate the installation of a 2000-m penstock.

Among the assumptions for Option 3 are:

- An assumed Head of 100 m at the discharge of the 12-in. pipe.

- There is no requirement for residual pressure downstream of the turbine. Residual pressure would be used to pressurize water lines for water distribution systems within the ANSU complex.
- A velocity in the pipe of 7 feet per second (fps).
- The length of the 12-in. pipe is approximately 2000 m.

Before committing to construction of any of the Options identified here, it is imperative that the assumptions be verified. Differences in heads or flow rates will have a dramatic influence on the amount of power generated by the facility.

Solution

For any of the three options considered here, a minimum of three differently sized turbines will be required to accommodate the broad range of discharge from the dam. The units are relatively small—similar to a 24-in. diameter centrifugal pump and a 50-hp motor. The units can be manufactured and shipped as discrete, fully assembled components such as turbines, generators, and control units. Installation at the powerhouse will require connecting the power shafts of the components, connecting both the control wiring and the power cables, connecting the intake pipes (Penstocks), installing isolation valves and installing all the equipment on footings pre-cast into the concrete floor of the powerhouse.

The powerhouse itself is planned to be a simple metal pole building with slab-on-grade construction. The building is expected to be on the order of 61 ft long by 24 ft wide.

For Options 1 and 2, the water conduit (penstock) from the outlet works of the dam to the powerhouse is estimated to be a 36- in. diameter pipe. Feeder penstocks to each of the units will branch off the main penstock outside the powerhouse wall. For Option 3, the 12- in. diameter pipe will be branched into the three turbines inside the powerhouse.

The powerhouse is envisioned to be staffed by operators a minimum of 8 hrs per day, and probably 24 hrs per day. The equipment is expected to be manually operated, to accommodate flow rates that are anticipated to change frequently.

Savings

As identified in the "Viability for ANSU" section (p 32), the savings in annual energy for Option 1 would be 227,760 kWh. Diesel fuel provides energy of approximately 12.7 kWh/gal. Thus, ~17,934 gal of diesel fuel will be saved annually by installing a powerhouse at the base of the dam.

The savings in annual energy for Option 2 would be 902,280 kWh. The annual diesel fuel savings for this powerhouse would be ~71,046 gal.

The annual energy savings for Option 3 would be 788,400 kWh. The annual diesel fuel savings for this option would be ~62,079 gal.

Investment

Because the units are relatively small, there is little cost difference for the equipment in any of the powerhouses considered here (Table 25). The major cost difference between the two powerhouses is the cost of the 2000-m penstock required for Option 2.

Table 25. Estimated costs for hydroelectric power.

Cost Element	Type of Cost	Cost for Work Performed in the United States	Estimated Afghan Cost*
For Option 1, the 26 KW Powerhouse at the Base of the Dam			
Equipment Cost	Initial construction	$1,000,000	$3,000,000
Building cost, including short coupled penstock	Initial construction	$230,000	$690,000
Annual O&M, excluding labor	Annual expense	$10,000	$30,000
O&M Labor (four full time employees)	Annual expense	N/A	N/A
For Option 2, the 103 KW Powerhouse at the end of the 2000-m penstock			
Equipment cost	Initial construction	$1,200,000	$3,600,000
Building cost	Initial construction	$192,500	$577,500
2000-m penstock	Initial construction	$2,700,000	$8,100,000
Annual O&M, excluding labor	Annual expense	$10,000	$30,000
O&M Labor (four full time employees)	Annual expense	N/A	N/A
For Option 3, the Powerhouse at the end of the 12 in. pipe			
Equipment cost	Initial construction	$1,000,000	$3,000,000
Building cost, including short coupled penstock	initial construction	$230,000	$690,000
Annual O&M, excluding labor	Annual expense	$10,000	$30,000
O&M Labor (four full time employees)	Annual expense	N/A	N/A
*Per the estimating protocols of this report, Afghan costs are estimated at three times the US costs.			

Simple payback

The simple payback calculations in Tables 26, 27, and 28 identify the number of years it will take to recover the initial (capital) cost of providing a working powerhouse, based on capital costs of $3.69 million (for a 26-kW powerhouse), $12.28 million (for a 103-kW powerhouse), and $3.69 million (for a 90-kW powerhouse), and various prices for fuel for each case. These calculations do not include the cost of annual O&M.

Table 26. Simple payback hydroelectric power for Option 1 (26 KW Powerhouse).

Parameter	Value	Unit	
Capital cost	3,690,000	Dollars, Afghan Cost	
KWH produced from 1 gal of diesel fuel in a diesel generator	12.7	KWHr	
Energy produced by the hydroplant	227,760	KWHr	
Number of gallons saved per year	17,933.86		
Cost per gallon of Fuel	$4.40	$10.00	$20.00
Dollars saved per year	$78,909.00	$179,338.58	$358,677.17
Number of years for payback	46.76	20.58	10.29

Table 27. Simple payback hydroelectric power for Option 2 (103 KW Powerhouse).

Parameter	Value	Unit	
Capital cost	12,277,500	Dollars, Afghan Cost	
KWH produced from 1 gal of diesel fuel in a diesel generator	12.7	KWHr	
Energy produced by the hydroplant	902,280	KWHr	
Number of gallons saved per year	71,045.67		
Cost per gallon of Fuel	$4.40	$10.00	$20.00
Dollars saved per year	$312,601.00	$710,456.69	$1,420,913.39
Number of years for payback	39.28	17.28	8.64

Table 28. Simple payback hydroelectric power for Option 3 (90 KW Powerhouse).

Parameter	Value	Unit	
Capital cost	3,690,000	Dollars, Afghan Cost	
KWH produced from 1 gal of diesel fuel in a diesel generator	12.7	KWHr	
Energy produced by the hydroplant	788,400	KWHr	
Number of gallons saved per year	62,078.74		
Cost per gallon of fuel	$4.40	$10.00	$20.00
Dollars saved per year	$273,146.46	$620,787.40	$1,241,574.80
Number of years for payback	13.51	5.94	2.97

Table 29. Hydroelectric power SIR estimates.

SIR (yrs)	Option 1, 26 KW Powerhouse			Option 2, 103 KW Powerhouse			Option 3, 90 KW Powerhouse		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.06	0.18	0.40	0.10	0.25	0.52	0.29	0.71	1.46
10	0.11	0.33	0.72	0.19	0.46	0.94	0.53	1.30	2.66
15	0.15	0.45	0.99	0.26	0.63	1.29	0.73	1.78	3.64
20	0.18	0.55	1.21	0.32	0.77	1.58	0.89	2.17	4.45
25	0.21	0.63	1.39	0.37	0.89	1.81	1.03	2.49	5.12
50	0.28	0.87	1.91	0.51	1.22	2.49	1.41	3.43	7.03

SIR

An assumed interest rate of 4 percent was used to calculate the savings to investment ratio. Table 29 lists the findings for all three options, and converts the annual fuel savings based on present value for a timeline of 5, 10, 15, 20, 25, and 50 yrs.

Biodiesel

Technology description

Biodiesel is an alternative to standard diesel fuel. Biodiesel is made from biological ingredients instead of petroleum, usually from plant oils or animal fat through a series of chemical reactions known as transesterification. Purified fats and oils are reacted with an alcohol (usually methanol or ethanol) in the presence of some catalyst, usually a strong base. The resulting products are esters (commonly referred to as biodiesel) and glycerol. The glycerol can then be used in soaps and other pharmaceutical uses.

Biodiesel is non-toxic, renewable, and environmentally friendly. It can be replenished through farming and recycling because it is easily accessible from plants and animals. Additionally, biodiesel itself is a solvent that is capable of removing build up in engines; its use can decrease engine wear and extend engine life. Biodiesel is biodegradable and decomposes at a rate four times faster than conventional diesel, easing environmental cleanup in the event of a spill.

Part of what makes biodiesel so appealing is that it can be made from numerous natural sources. Although animal fat can be used, plant oil is the largest source of biodiesel. The calorific value of biodiesel is about 37.27 MJ/L (Elsayed, Matthews, and Mortimer 2003), or about 133,580 Btu/gal.

Biodiesel is safe and can be used in diesel engines without modification. While it is possible to use biodiesel in its purest form it is typically blended with standard diesel fuel. Biodiesel has better lubricating properties and much higher cetane ratings than today's lower sulfur diesel fuels. Pure biodiesel produces no sulfur emissions, which are linked to acid rain, reduces hydrocarbon emissions known to cause cancer by two-thirds and decreases carbon monoxide emissions by almost half.

Unfortunately, biodiesel engines produce an increased amount of nitrous oxide emissions, which leads to smog. Additionally, biodiesel has a decreased fuel efficiency of roughly 10 percent compared to pure diesel. Current biodiesel prices are roughly equal to those of conventional diesel, but supply and availability of biodiesel has caused significant variation in prices across locations.

Existing usage

Biodiesel plants are prevalent in the United States and Europe. In 2008, the largest producer of biodiesel was the European Union with 1.7 billion gal of production per year, followed by the United States with 677 million, Brazil with 300 million, and Argentina with 250 million. In the United States alone, there are approximately 170 biodiesel plants with a production capacity of 2.7 billion gal (Arden and Fox 2010).

Viability for ANSU

For security purposes, producing biodiesel on site would reduce transportation costs and reduce travel required for fuel delivery. However, the biodiesel yield for safflower is only roughly 83 gal acre. Therefore 1 acre of safflower generates roughly 2877 kWh/yr based on 30 percent efficiency of the generator. Given an estimated peak load of 16 MW, a 10 MW sustained load will require 87,600,000 kWh/yr. A plant would require 1522 acres of oil crops to produce roughly 5 percent of the required power for ANSU.

Given the size of the complex and the potential for additional expansion producing the biomass required for the transesterification process on site is not feasible. However, the ANSU complex may select to purchase land offsite for soybean or other crop farming that could in turn be used to provide biodiesel. If soybeans are grown, the ANSU will enable local farmers with the ability to provide for their families while reducing the poppy pro-

duction in the country. The biodiesel processing plant could be built on site eliminating the need to transport flammable biodiesel on the only access road to the complex. However large amounts of soy would have to be hauled into the site, increasing costs associated with production.

Solution

Given the present technologies available, limited space inside the complex, and the byproduct of glycerol, biodiesel fuels and its associated products should not be grown and processed on site. However, the production of biofuel would be a viable option to alleviate cost of fuel for the complex if there were adequate space for biomass production, and if efforts were made to build a biodiesel production plant. Space permitting, the ANSU complex could potentially house the production plant, although additional traffic studies would be required to determine if the two-lane access road is suitable for the additional traffic caused by transporting biomass. Cooperation with USAID is recommended to achieve a solution that would create a biodiesel power plant in the Kabul area and that would establish a program to educate farmers in soybean farming techniques.

Savings

Given the FBCF of $4.40/gal, and a biodiesel production cost in the United States of roughly $2.10/ gal, plant savings will be 49 percent. Not included in this price is the cost to farmers for producing biodiesel crops, which would be done through a USAID or other humanitarian aid based program. Additionally, glycerol can be sold for use in epoxy resins and paper reinforcing agents. The current cost of glycerol is $0.05/lb; this can also be resold to reduce the cost of the plant.

Investment

Table 30 lists biodiesel power plant cost estimates.

Table 30. Biodiesel power plant cost estimates, (including the Afghan construction multiplier of three).

Parameter	Cost
Biodiesel power plant— $3/gpy	~$600,000–$900,000 and 2 acres of land (Red Birch Energy 2010)
O&M	$36,000/yr
Transportation costs	$48,000/yr
Methanol consumption	$50,000/yr
Farmer subsidies	Paid for by another agency

Simple payback

Table 31 lists simple payback for biodiesel estimates.

Table 31. Simple payback for biodiesel estimates.

Simple payback (yrs)	$4/gal	$10/gal	$20/gal
$600k plant	1.30	0.38	0.16
$900k plant	1.96	0.57	0.24

SIR

Table 32 lists the SIR estimates for biodiesel technology.

Table 32. Biodiesel SIR estimates.

SIR (yrs)	$600k plant cost			$900k plant cost		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	3.13	11.44	26.28	1.29	6.83	16.72
10	5.70	20.85	47.88	2.34	12.44	30.46
15	7.82	28.57	65.64	3.21	17.05	41.76
20	9.56	34.93	80.23	3.93	20.84	51.04
25	10.99	40.15	92.22	4.51	23.95	58.67
50	15.11	55.21	126.82	6.21	32.94	80.68

Long-term considerations (O&M, complexities, replacement parts, labor skill)

Environmental and safety

There would be concern with the workers' environment and safety. OSHA considers biodiesel production facilities to be chemical plants. The handling/storage of flammable liquids (both the intermediate products and final product diesel) is very dangerous.

Feedstock and water demand

The plant will require a consistent feedstock and water to keep it operational. This will require an almost daily transportation of the materials into the plant complex.

O&M costs

Biodiesel plant O&M costs are similar to those of fossil fuel plants of similar size (area). Additionally, because of the smaller size recommended, O&M costs would amount to a larger percentage over the overall annual

costs compared to a larger plant. Replacement parts are expected to be harder to procure due to the newness of this technology in Afghanistan. The chemical process is complex and will require careful monitoring and oversight to avoid serious safety violations that could result in injury or even death, and/or poor production resulting in unsuitable final (biodiesel) products.

Labor

The plant will require a trained and dedicated staff. Also, to increase the success of this project over the long term, it may be best to assess the size of the plant to meet the needs of the ANSU complex, and then to oversize the plant to capitalize on the economies of scale.

Material hauling and storage

As noted above, another consideration is the amount of additional biomass required daily to keep the plant operational. This material would have to be transported into the complex almost every day via trucks. To alleviate the large amount of daily traffic that would otherwise pass through main gate, it is recommended to have a “service entrance” to allow delivery of biomass and other materials. It is also recommended to maintain a minimum of 7 days biomass material on hand in a covered facility. Finally, all production residue will need to be transported off-site to an approved location.

Solar wall

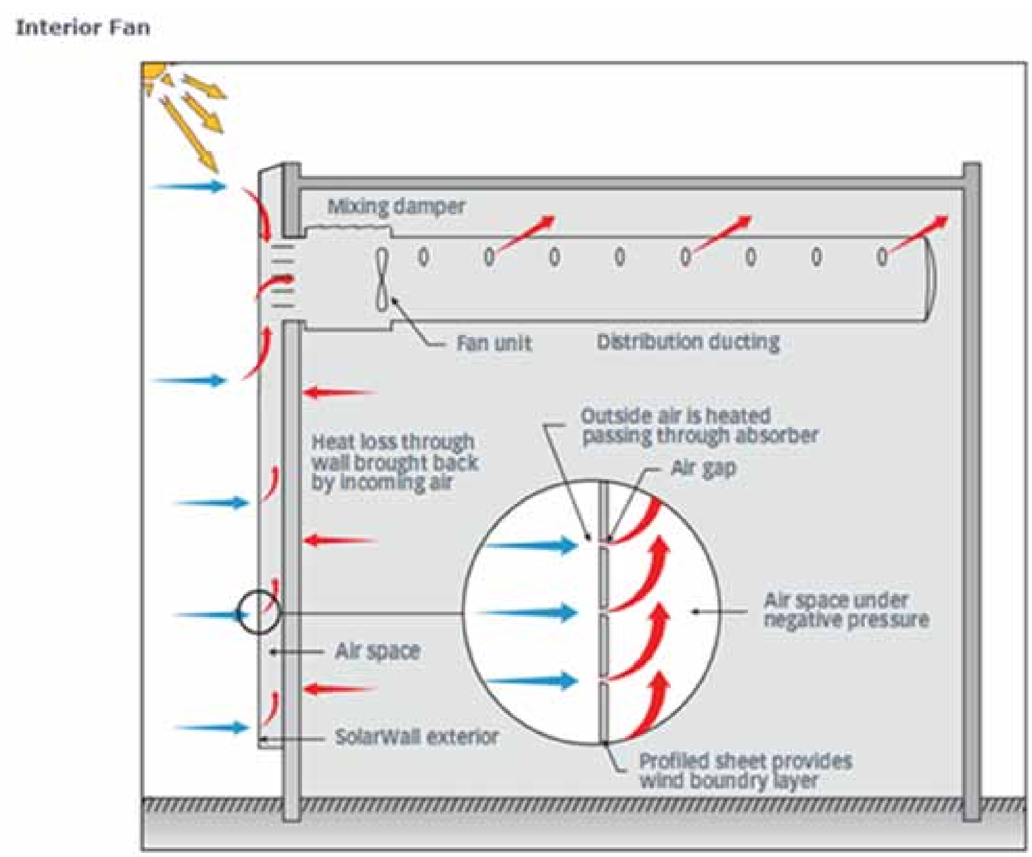
Technology description

The solar wall heating system contains internal and external components. One of its multiple applications includes using solar energy to heat and ventilate indoor spaces, and to heat air for manufacturing processes and agricultural crop drying applications. The design of the solar wall is optimized to maximize energy delivery with a minimum amount of static pressure in the airflow.

The solar wall (Figure 13) uses specially perforated collector panels installed inches away from a south facing wall, creating an air cavity. Solar radiation from the sun heats the metal cladding attached to the wall. As the metal clad wall is heated, ventilation fans create a negative pressure in

the air cavity, drawing solar-heated air in through the panel perforations. A specific design of the panel and framing system is used to control the amount of airflow through the perforations. Enabling the control of the amount of airflow will allow a consistent draw across the entire wall surface and will ensure that cooler air beyond the heated boundary layer is not introduced into the air stream.

Since hot air rises, the air is generally taken from the top of the wall, ensuring that all of the solar heat produced is collected. The heated air is then routed into the building through the HVAC intake. The energy load on the conventional heater is reduced due to the air entering the air handler already being preheated. Solar walls can be easily integrated into existing buildings, and can cost-effectively reduce energy consumption by large amounts. Additionally, solar walls can greatly increase the efficiency of heat recovery ventilator (HRV) systems by preheating incoming air.



(Source: Conserval Engineering, Inc., 2010, http://solarwall.com/en/products/solarwall-air-heating/how-it-works.php.)

Figure 13. Interior fan system.

Existing usage

Solar walls are a proven renewable energy technology that are used extensively throughout DOD installations. On a sunny day, a solar wall can provide sufficient air preheating to meet the needs of the building it serves.

Viability for ANSU

Afghanistan has great potential for the use of solar walls since the sun shines approximately 300 days a year, i.e., solar walls can provide maximum performance throughout the year in Afghanistan. Also, solar walls require virtually no maintenance; they are integrated into the building's structure and contain no moving parts. Installing a solar wall over masonry will also protect the façade from rain and moisture, which can cause bricks to crumble. Additionally, a solar wall has the ability to heat and cool a facility during summer and winter months. During summer months a summer bypass intake is used to draw out the warm air and move in cooler air. Due to its low maintenance requirement and its applicability throughout the year, solar wall placement is virtually limitless throughout the ANSU complex.

Solution

Its ease of installation and low maintenance requirement make solar wall technology a viable option for the ANSU site. A simple analysis of where the sun most effectively shines on the buildings is needed to properly place the Solar Walls. Appendix F provides complete feasibility analyses for the use of the Solar Wall at ANSU for an auditorium, dining facility, field house, and a recreational facility. The analyses were done using the Solar Air Heating Project Model spreadsheet module from the Clean Energy Project Analysis Software suite, a product from RETScreen® International,* which is managed by the CanmetENERGY Research Center of Natural Resources Canada.

* http://www.retscreen.net/ang/home.php

Savings

An analysis of the feasibility of adding a solar wall to Bldg 164 (the Auditorium) assumed:

- an FBCF of $4.40/gal
- an initial cost for heating systems of $720,710
- the Auditorium to be full (2000 person capacity) when in use
- the Auditorium to be in operation 10 hrs/day, 7 days/wk (Based on the Auditorium's "100% design" plans, this schedule will require a design airflow rate of 10,337 m^3/h.)
- to accommodate the hot summer season, the solar wall would not be in operation from June to August.

Based on these assumptions, the analysis estimated that adding solar wall technology to solar wall to Bldg 164 would yield annual savings of $82,948.

Investment

The solar wall system will cost $720,710. Maintenance and operational costs come to $5,978. Additionally, once the Solar Wall is emplaced, there is only minor maintenance required. Local O&M personnel will not require advanced training to maintain the solar walls.

Simple payback

Simple payback for the auditorium will occur in 8.7 yrs (Table 33).

Table 33. SolarWall cost summary and payback for auditorium.

Bldg Analyzed	Initial Cost ($)	Savings ($)	O&M ($)	Payback (yrs)
Auditorium	$720,710	$82,948	$5,978	8.7

SIR

Table 35 lists the SIR for the ($600k and $800k) SolarWall system.

Table 34. SolarWall system SIR ($600k and $800k).

SIR (yrs)	$600k system			$800k system		
	$4.4/gal	$10/gal	$20/gal	$4.4/gal	$10/gal	$20/gal
5	0.76	1.72	3.43	0.63	1.43	2.86
10	1.38	3.13	6.25	1.15	2.61	5.21
15	1.89	4.29	8.57	1.57	3.57	7.14
20	2.31	5.24	10.48	1.92	4.37	8.73
25	2.65	6.02	12.05	2.21	5.02	10.04
50	3.64	8.28	16.56	3.04	6.90	13.80

Long-term considerations (O&M, complexities, replacement parts, labor skill)

O&M is relatively simple with only a fan for a moving part and a programmable logic controller (PLC) acting as a differential controller to turn the fan on and off. Recommended O&M involves checking the fan and controller quarterly, and replacing or repairing either as needed. It is also recommended that a manual switch be installed to turn the fan on and off if the controller is inoperable. Spare parts would be fan motor, belts, and the PLC. Skills needed are electrical and mechanical.

Solar air collector

Technology description

Solar air collectors are relatively simple renewable energy systems that provide heated air (via a solar plate/collector) to the interior of a building using a small fan. They are installed either on a roof or an exterior (south facing) wall for heating one or more rooms.

The collector has an airtight, insulated metal frame, and a black metal plate (with glazing on its face) for absorbing heat. Solar radiation heats the plate, which, in turn, heats the air in the collector. An electrically powered fan or blower draws air from the room through the collector, and blows it back into the room. Roof-mounted collectors require ducts to convey air between the room and the collector. Wall-mounted collectors are placed directly on a south-facing wall, and holes are cut through the wall for the

collector air inlet and outlets. Most installed solar air collectors can supply 20–30 percent of a building's total annual heating load.

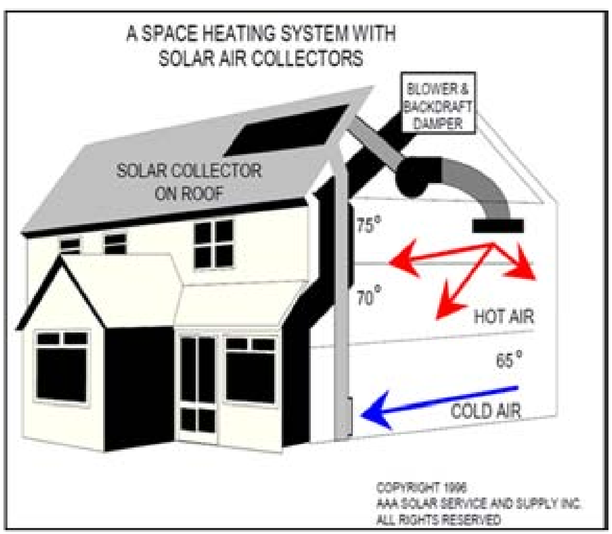
Advantages of solar air collector technology include:

- better absorbance of solar energy without restriction of direct solar gains in comparison to typical solar passive technologies
- better timing of solar heat with usage of thermal wall, when there is no sunshine heat is released from the wall
- reduced costs of energy consumption for the building
- in comparison with water collectors, no requirement for chemicals (antifreeze), and no danger of chemical loss in the building if damaged
- potential for integration with HVAC systems, e.g., to preheat air
- potential for use in very low-energy residential, commercial, and institutional buildings.

Limitations of solar air collector technology include:

- very small heat capacity in comparison with water collectors
- large amount of air that should be supplied to a building to obtain a higher inside temperature.

Figure 14 shows the solar collector process.



(Source: AAA Solar Supply, Inc. 1996.
21st Century Energy Solar Air Collector Installation Guide. AAA Solar Supply, Inc.,
http://www.aaasolar.com/ProdLit/SunAire/AirCollectorManual.pdf.)

Figure 14. Solar air collector.

Figure 15 shows a roof-mounted solar collector application.

(Source: Home Power, Issue 118, April & May 2007, page 98.)

Figure 15. Roof-mounted solar collector.

Viability for ANSU

Solar air collectors are viable for the ANSU complex. They are applicable to all types of buildings that have good solar access on the roof and are a viable option for both new construction and retrofits. Wall applications are best mounted on S or SE facing walls.

Solution

An example roof-mounted solar air collector for a typical barracks building would have following parameters:

- Building size: 17,000 sq ft
- Annual heat demand: 140,000 kWhrs of electricity
- Or 10,960 gal of diesel = $48,220 annual cost savings.

Total heat displaced by the system annually would be:

- 2,070 therms,
- 60,666 kWhrs = 4,777 gal of diesel = $21,018.

Investment

- Cost to install: $120,000 in Afghanistan

Simple payback

Table 36 lists the simple payback calculations for solar air collector technology.

Table 35. Simple payback solar air collector.

Simple payback (yrs)	$4.40/gal	$10/gal	$20/gal
$120K system	5.7	2.5	1.3

SIR

Table 37 lists SIR calculations to a solar air collector technology.

Table 36. SIR solar air collector.

SIR (yrs)	$400K system		
	$4.4/gal	$10/gal	$20/gal
5	0.78	1.77	3.54
10	1.42	3.23	6.46
15	1.95	4.43	8.85
20	2.38	5.41	10.82
25	2.74	6.22	12.44
50	3.76	8.55	17.10

Long-term considerations (O&M, complexities, replacement parts, labor skill)

O&M for solar air collector technology is similar to that for similar to solar wall technology. Solar air collectors are relatively simple; a fan is the only moving part, and a Programmable Logic Controller (PLC) acts as a differential controller to turn the fan on and off. Recommended O&M is to check the fan and controller quarterly, and to replace/repair either as needed. It is also recommended to install a manual on/off fan switch so operators can operate the fan if the controller is inoperable. Spare parts would be fan motor, belts, and the PLC. Skills needed are electrical and mechanical.

It is also recommended to check the mounting connection against the roof and/or wall at least monthly to ensure a tight seal and no moisture infiltration into the building.

Demand and energy reduction strategies

Technology description

Incorporating energy efficiency, renewable energy, and sustainable design features into the ANSU campus has become an important priority with the senior leadership at CSTC-A. Current facility standard designs at the ANSU already incorporate some conservation measures such as minimal use of heating and air conditioning, efficient lighting, and good use of insulation in the walls and ceilings. However, additional measures are available that can further reduce both demand and energy consumption without compromising comfort and mission accomplishment. Because energy-efficient buildings reduce energy consumption and the adverse environmental impacts of pollution generated by energy production, it is often considered to be the cornerstone of sustainable design. This section addresses specific strategies to achieve energy efficiency.

Low-energy building design is not simply the result of applying one or more isolated technologies. Rather, it is an integrated whole-building process that requires action on the part of the design team throughout the entire project development process. The whole-building approach is easily worth the time and effort, as it can save 30 percent or more in energy costs over conventional building techniques. Moreover, low-energy design does not necessarily have to result in greatly increased construction costs. One of the key approaches to low-energy design is to invest in the building's envelope (e.g., windows, walls, roofs) to reduce heating, cooling, and lighting loads, so that the building, in turn, requires smaller, less costly HVAC systems. Additionally, these improvements are all non-electromechanical measures. In designing low-energy buildings, it is important to understand that the underlying purpose of the building is neither to save—nor to use—energy. Rather, the building must serve the occupants and their activities. An understanding of a building's occupancy and activities can lead to building designs that not only save energy and reduce costs, but also improve occupant comfort and workplace performance.

Solution

The whole process of reducing the demand loads and overall energy consumption begins at the initial planning and design (P&D) charrettes and is carried all the way through to implementation. Both the customer and

architect/engineer (A/E) firm must make a determined effort to address these measures as part of the facility designs. The process would be:

1. Consider separate sessions at the P&D charrettes to address nothing but energy conservation measures.
2. Once those measures are applied, HVAC equipment can be sized accordingly, most notably, sized smaller than the one for an original/base building design without the reduction measures.

Simplicity is required due to Afghanistan's harsh environment, its less advanced in-house technical capability, the high cost of fuel, security concerns, lengthy distances, and the relatively long time to receive replacement parts. Reducing project complexity while maintaining the architectural theme will also reduce future O&M concerns.

3 Demand and Energy Conservation Measures Checklist

The information in this checklist provides users and designers with information that will help them select and prioritize energy conservation measures to consider and the type of energy efficient equipment to purchase.

Tier 1 Energy Conservation Measures

Tier 1 lists three major areas that provide the greatest return on investment:*

- *Lighting, Water and Ductwork Sealing and Insulation*. The following sections specify the parameters for installing four of the measures outlined:
  - C.1 Energy-efficient lighting and fixtures (p 104)
  - C.2 Programmable thermostats (p 105)
  - C.3 Water efficiency (p 105)
  - C.4 Ductwork sealing and insulation (p 105).
- *Envelope Sealing and Installation*. The following section provides the recommended insulation levels for various areas (e.g., attic, crawl space of basement, and basement wall) of the building envelope by climate zone:
  - C.5 Envelope sealing and insulation (p 105)
- *HVAC*. The following sections specify the type of HVAC equipment that should be installed to operate at peak energy efficiency for the climate zone, including specifics on energy management systems and recommended settings:
  - C.6 Ventilation (ductwork sealing and insulation) upgrades (p 107)
  - C.7 Energy management system (p 107)
  - C.8 HVAC (p 108).

Tier 2 Energy Conservation Measures

Tier 2 lists five major areas that provide solid return on investment:†

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* Energy conservation technologies are described in detail in Appendix C to this report (p 103).

† Tier 2 measurements may require more time than Tier 1 measurements to achieve savings.

- *Water Heater*. The following section explains what type of water heater equipment to use depending on variable such as whether CSTC-A is willing to pay a little more upfront to reduce water heating bills (Simple payback determination):
  - C.9 Water heater (p 109)
- *Site Design and Building Orientation*. The following section explains ideal overall site design and recommended facility orientation:
  - C.10 Site design and building orientation (p 109).
- *Window, Door and Skylights*. The following section details what type of windows, doors and/or skylights should be purchased. A gradation of U-Factor and solar heat gain coefficient (SHGC) numbers are provided by climate zone to determine the rate of heat/cooling transmissions at various window/door/skylight protection levels. The lower the U Factor the more energy efficient the window, door, or skylight will be. The lower the SHGC number, the less solar heat it transmits and the greater it's shading ability. A high SHGC rating, the more effective the equipment is at collecting solar heat gain during the winter.
  - C.11 Energy-efficient replacement windows, doors, and skylights (p 110)
- *Passive Solar Design*: Using South facing windows with overhangs that shade in the summer and allow winter sun will reduce the need for heating energy. Trombe walls are South facing walls that are painted dark, covered in glazing, built of mass construction, and do not have insulation so that the heat will drive through in the winter. There is typically very little heat through these type walls in the summer due to the high summer sun angle. Another type of passive design is solar cooling with the solar chimney and low operable vents on the North wall. This may work well at this site especially due to the predominant North winds in the summer.
  - C.10 Site design and building orientation (p 109)
- Motor/Pumps. The following section provides a web link that describes the scope of products and nominal efficiency levels for motors/pumps that are used to operate energy equipment:
  - C.12 Energy-efficient replacement motors and pumps (p 111)
- *Building Management System*. Table 37 lists guidance on building management and automation control systems.

Table 37. Guidance on building management and automation control systems.

Energy Conservation Measures (See Appropriate Table for Specs.)	Applicable to Small Detached Buildings	Applicable to Large Buildings (> 50,000 sq ft)	Benefits of Energy Conservation Measure	
TIER 1				
Lighting, Fixtures and Controls (See C.1, p)	Yes	Yes	ENERGY STAR RATED (per 2000 sq ft of building)	Life-Cycle Energy Saved Annually (kWh)
			Lighting	450
			Indoor Fixtures	1,740
			Outdoor Fixtures	2,660
Programmable Thermostat (See C.2)	Yes	Yes	Save by properly setting their programmable thermostats and maintaining those settings. Education is also an important component to realizing the savings from programmable thermostats.	
Water Efficiency (See C.3)	Yes	Yes	Water Conservation Measures	Justification
			WaterSense-Labeled Toilets	Toilets account for approx. 27% of indoor water use
			WaterSense Faucets and Faucet Accessories	Faucets account for approx. 16% of indoor water use
			Replace showerheads to less than 1 gpm flows	Showers account for approximately 17% of indoor water use
Ductwork Improvements (See C.4)	Yes	Yes	Ducts that move air to-and-from a forced air furnace, central air conditioner, or heat pump are often big energy wasters. Sealing and insulating ducts can improve the efficiency of your heating and cooling system by as much as 20% (sometimes much more).	
Envelope Improvements (See C.5)	Yes	Yes	Sealing and insulating the "envelope" or "shell" is often the most cost effective way to improve energy efficiency and comfort. ENERGY STAR estimates can save up to 20% on heating and cooling costs (or up to 10% on the total annual energy bill) by improved sealing and added insulation. Note: A key component is to reduce <u>thermal bridge losses</u> by insulating the conductive material creating the bridge. Thermal bridge losses are about 30% of all total building envelope losses. Consider “doubling” the thickness of the walls and R-value in the ceiling.	
Ventilation Upgrades (See C.6)	Yes	Yes	Without mechanical ventilation to provide fresh air, moisture, odors, and other pollutants can build up inside a home. Mechanical ventilation systems circulate fresh air using ducts and fans, rather than relying on airflow through small holes or cracks in a home’s walls, roof, or windows. Some of the benefits of mechanical ventilation are better indoor air quality, more control of air flow and improved comfort.	
Install Energy Management Controls (See C.7)	Yes	Yes	Energy management controls are used to optimize building systems resulting in cost savings and better comfort	
Cooling Equipment (See C.8)	Yes	Yes	Heating and cooling costs are nearly half of the facility’s total energy bill. If mini-split heat pump units are used, install an ENERGY STAR qualified model and reduce cooling costs by 30 percent. <u>Avoid resistive heating if possible</u>, a very inefficient way to heat electrically. <u>Radiant Floor Heating:</u> Use in conjunction with the solar water heater	
Heating Equipment (See C.8)	Yes	Yes		

TIER 2			
Water Heating (See C.9)	Yes	Yes	Water heating is the second largest energy expenditure behind heating and cooling. ENERGY STAR qualified water heaters include smart design enhancements that offer significant improvements in efficiency and performance. If district heating is not implemented, consider using the waste heat from the diesel generator exhaust to heat DHW for use in the support area. Consider using a grey water heat recovery system (non-electro-mechanical device) to recover heat from grey water. Ideal use in DFACs, fitness facilities, and other facilities using large quantities of hot water.
Site Design and Layout (See C.10)	Yes	Yes	Optimizes performance based on site design and facility orientation
Windows, Doors and Skylights (See C.11)	Yes	Yes	ENERGY STAR qualified windows, doors and skylights can help reduce energy bills up to 15 percent. Estimated savings vary from region-to-region depending on current heating and cooling costs and are generally greatest where there are hot summers, cold winters or both. Afghanistan considered “Mountain” region. Passive solar options: Trombe wall, solar chimney
Motor/Pumps (See C.12)	No	Yes	Look for and specify National Electrical Manufacturers Association (NEMA) Premium® to optimize motor systems efficiency, reduce electrical power consumption and costs, and improve system reliability.
Install Building Management System (See C.13)	No	Yes	Energy management controls are used to optimize building systems resulting in cost savings and better comfort

4 Conclusions and Recommendations

Conclusions

This work reviewed and evaluated the feasibility of commercially available renewable energy technologies for application at ANSU and its supporting facilities located in Qargha, Kabul, Afghanistan, to reduce the use of, or to replace fossil (diesel) fueled electrical generators.

This work concludes that renewable energy technologies are feasible for the Afghanistan National Security University Complex. Table 40 (the same as Table ES1 in the Executive Summary) lists an economic summary of the renewable energy technologies examined during the study. However, proper implementation and sustainment of these technologies will require:

1. A carefully planned and designed system
2. A competent contractor to install the systems
3. A properly executed commissioning or post-construction verification program
4. A resourced and trained O&M program.

Recommendations

Numerous energy conservation measures are recommended to reduce both the overall electrical demand (kW) and the corresponding energy consumption (kWh).

Feasible renewable energy systems

Table 38 (the same as Table ES2) lists the renewable energy systems that are recommended for the ANSU complex.

Table 38. Feasible renewable energy practices.

Feasible Renewable Energy Practice	Reason for Feasibility
Solar panels (ground-mounted photovoltaic)	• Historical weather data suggest the use of photovoltaics is both cost effective and efficient. • Photovoltaics can provide a good percentage of the overall power and energy requirement, all located in one area.
Wind turbines	• Geography of the ANSU site indicates a much higher wind potential coming from the North than regional mapping suggests.
Solar walls	• Ease of installation • Cost efficiency • Potential to meet the primary heating need of the site.
Solar air collectors	• Ease of installation • Ability to match a good percentage the high winter heating load.
Solar DHW	• Solar insolation data suggest that solar DHW has the potential to reduce water heating requirements for DFAC and barracks.
Biodiesel	• USAID and Afghan combined venture needed. More than cost effective than pure diesel, crops are available to replace poppy production for energy usage. Only successful if specified crops are available year-round for fuel production.
Waste-to-energy - incineration, including biomass material (power and heat)	• Waste reduction of 80–90% • Energy production for 0.4–MW plant.

Unfeasible renewable energy practices

Table 39 (the same as Table ES3) lists the renewable energy systems that are considered currently unfeasible for the ANSU complex.

Table 39. Unfeasible renewable energy practices.

Unfeasible Renewable Energy Practice	Reason for Unfeasibility
Solar PV (building integrated)	• Inverter reliability issues • High O&M costs • Provides a limited amount of overall power/
Hydropower	• Qargha Dam has and outlet structure and only enough head to provide ~90 kW of energy, for an annual production of about 788,400 kWhrs.
Geothermal power plant	• High costs for drilling • Time intensive to complete suitable site survey, i.e., would not be operational before ANSU site was completed.

Unfeasible Renewable Energy Practice	Reason for Unfeasibility
Fuel cells (not listed in Table 40)	• Outside fuel source still required that is not readily available. • Cannot use diesel as fuel.
GSHPs	• Cost-ineffective (since almost all buildings only require heating, this expenditure).
Anaerobic digestion	• Economically unfeasible. (Simple payback greater than 20 yrs; takes 50 yrs for SIR to be greater than 1.)
WTE – gasification (not listed in Table 40)	• Extensive labor required to reduce waste to acceptable size. (Incineration is a better option.)
WTE - Thermal Depolymerization (not listed in Table 40)	• Cost ineffective • High maintenance • Only one commercially available product is on market, for much larger scaled waste stream.

Future microgrid consideration

Once it has been determined which renewable energy technologies will be used at ANSU, it will be necessary to consider how all these systems will function together, alongside the conventional engine driven generators and possibly the local utility grid. To fully optimize both fossil fuel power generation and the renewable energy technologies implemented at ANSU, at least a rudimentary microgrid capability must be developed. The microgrid must intelligently integrate all the generation assets with the loads to ensure that power is always available for the most critical mission facilities. Due to the intermittent nature of some of the renewable energy technologies, e.g., wind and solar, it will also be essential to include some means of energy storage, which will also become a major component of the intelligent microgrid. In this way, true energy security and sustainability will be achieved

Table 40. Renewable energy technology summary.

Feasibility	Technology	Size	Land Use	Capital Cost Afghanistan	Annual O&M Cost– Afghanistan	Simple Payback (yrs)	Years to SIR > 1	Annual Fuel Savings (gals)	% Diesel Fuel Reduction
Feasible	Solar Air Collector	5,050 m²	______	$120,000	$3,000	5.7	10	5,000	0.05%
	Solar Wall (Auditorium)	2,600 m²	______	$721,000	$6,000	8.7	10	19,000	0.2%
	Biodiesel	200,000 gpy (gal/yr)	2000 acres	$900,000	$180,000	2	5	105,000	1.0%
	Waste-to-Energy (WTE) Incinerator	0.4 MW (16 tons/day)	0.5 acre	$3 million	$430,000	4.5	10	152,000	1.5%
	Wind	1000 kW	<1 acre each	$6 million	$75,000	8.2	15	167,000	1.6%
	Solar DHW Heater	250,000 L/d	2500 m²	$8 million	$15,000	11	15	165,000	1.6%
	Solar Photovoltaic (PV) Ground-Based	2 megawatt-peak (MWp) (fixed tilt)	20 acres	$18 million	$70,000	15	15	273,000	2.7%
	Totals			**$37 million**	**$779,000**	**9.4**		**886,000**	**8.7%**
Unfeasible	Building Integrated PV	x kW - x kW	______	N/A	N/A	N/A	N/A	N/A	N/A
	Hydropower	90 kW	______	$4 million	$30,000	13.5	24	62,000	0.6%
	Anaerobic Digestion - Wastewater Treatment Plant (WWTP)	140,000 gal/day	<1 acre	$840,000	$9,000	23.8	>50	10,000	0.1%
	Geothermal Power Plant	20 MW		$300 million		10.5	15	6,508,000	64.0%
	GSHPs	871 m (borehole length)	0.25 acre	$600,000	$60,000	N/A	N/A	N/A	N/A
	Totals			**$305 million**	**$99,000**	**10.5**		**6,580,000**	**64.7%**

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Acronyms and Abbreviations

Term	Spellout
AED	Afghanistan Engineer District (North & South)
AFC	Alkaline fuel cell
AFCEE	Air Force Center for Engineering and the Environment
AFUE	annual fuel utilization efficiency
ANA	Afghan National Army
ANSU	Afghanistan National Security University
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
CDD	total cooling degree days
CEERD	US Army Corps of Engineers, Engineering Research and Development Center
CERL	Construction Engineering Research Laboratory
CFL	Compact Fluorescent Lighting
CONUS	Continental United States
COTR	Contracting Officer's Technical Representative
CSTC-A	Combined Security Transition Command – Afghanistan
CWT	Changing World Technologies
DC	District of Columbia
DFAC	Dining facility
DHW	Domestic Hot Water
DMFC	Direct Methanol Fuel Cell
ERDC	Engineer Research and Development Center
FBCF	Fully Burdened Cost of Fuel
FOB	Forward Operating Base
gpy	gallons per year
GSHP	Geothermal (Ground Source) Heat Pump
GSL	Geotechnical and Structures Laboratory
HDC	USACE Hydroelectric Design Center
HDD	heating degree days
HET	High efficiency toilet
HRV	Heat Recovery Ventilator
HVAC	heating, ventilating, and air-conditioning
IED	Improvised Explosive Device
JP-8	"Jet propellant 8," a kerosene-based fuel
JPIO	Joint Program Integration Office
KOH	potassium hydroxide
kWp	kilowatt-peak

Term	Spellout
MCFC	Molten Carbonate Fuel Cell
MW	Megawatt
MWp	megawatt-peak
NATO	North Atlantic Treaty Organization
NEMA	National Electrical Manufacturers Association
NMAA	National Military Academy of Afghanistan
NREL	National Renewable Energy Laboratory
NTM-A	North Atlantic Treaty Organization (NATO) Training Mission – Afghanistan
O&M	operations and maintenance
PAFC	Phosphoric Acid Fuel Cell
PEMFC	Proton Exchange Membrane Fuel Cell
PV	Photovoltaic
SHGC	Solar Heat Gain Coefficient
SIR	savings to investment ratio
SOFC	Solid Oxide Fuel Cell
US	United States
USACE	US Army Corps of Engineers
USAID	US Agency for International Development
USFOR-A	US Forces – Afghanistan
VOC	volatile organic compound
Wp	watt-peak
WTE	Waste-to-Energy
WWTP	Wastewater Treatment Plant

Appendix A: Wind Data

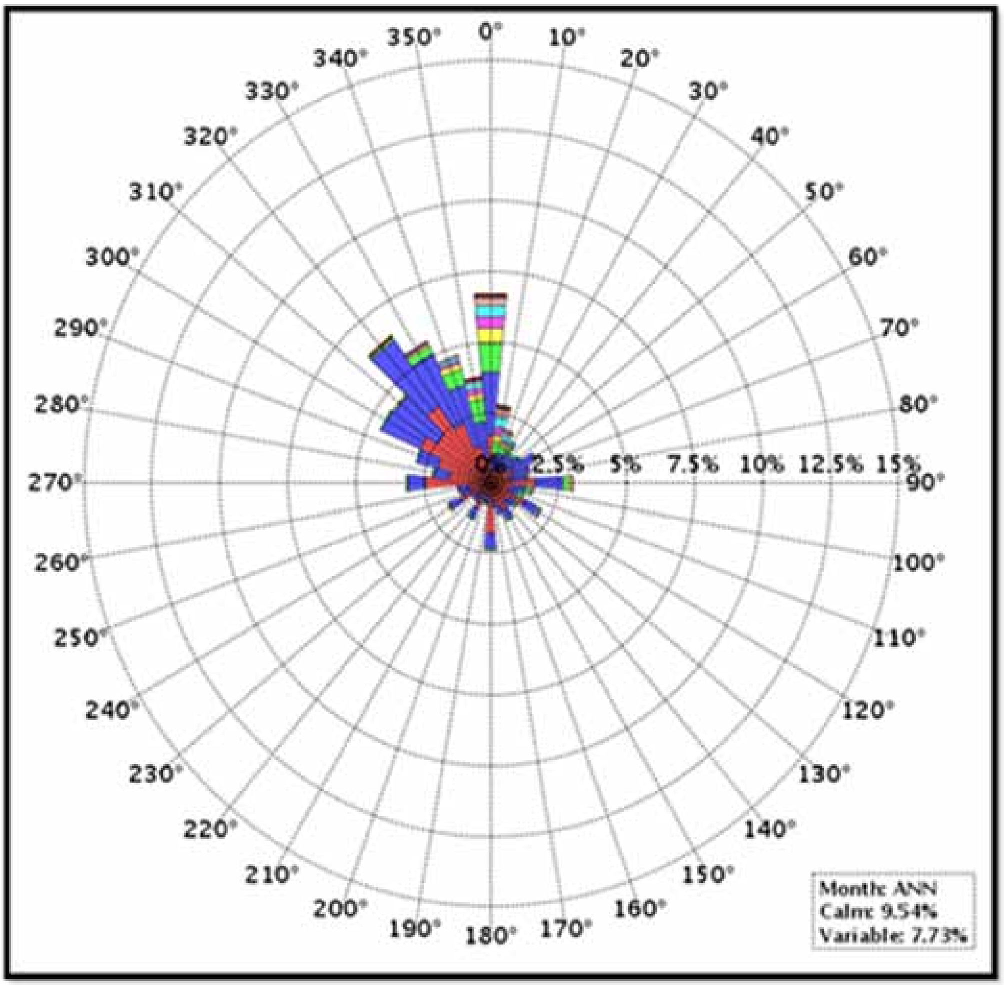

Figure A1. Kabul International Airport wind rose.

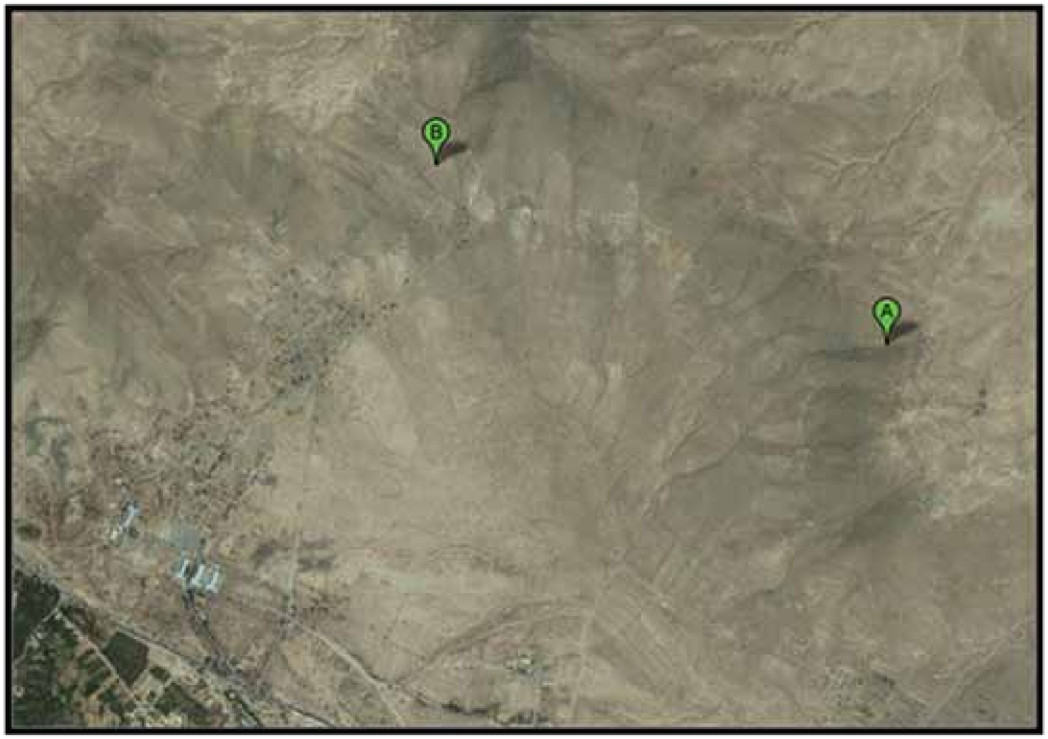

Figure A2. Wind data collection points of interest.

Appendix B: Reconnaissance Report - Hydropower Potential at Qargha Dam

Revision 3
Reconnaissance Report
To Determine
Hydropower Potential at Qargha Dam, Afghanistan

In Support of Alternate Energy Sources
for the
Afghan National Security University Complex

Author:
G. Charles Allen, Jr., PE
Hydroelectric Design Center
Portland District, US Army Corps of Engineers

Date
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Revision 1: 05 July 2010
Revision 2: 09 August 2010
Revision 3: 19 August 2010

B.1 Purpose

This Document is intended to provide a reconnaissance level investigation into the potential for hydropower generation at Qargha Dam, Afghanistan. It is anticipated that any power generated as a result of this report will be used to reduce the consumption of fossil fuel generated power at the Afghan National Security University complex.

B.2 Executive summary

Hydropower is not considered a viable source of power to reduce the ANSU's dependence on power generated from fossil fuels. Based on good quality data and reasonable assumptions, it appears that the maximum possible power available from the site is about 100 kW.

B.3 Considerations and assumptions

The flow data used in these calculations is based on measurements made at a gauging station "downstream of Qargha Dam." How accurately this flow information reflects the actual flow out of the Qargha Reservoir is unknown. The seasonal elevation variation of Qargha Lake is not known. If the depth of the lake drops below 25 m, then the power numbers presented here will decrease. In all likelihood, the power outputs presented here are optimistic. Based on information available for this study, the average output from a generating station located at the base of the dam is 26 kW.

If it were built in the United States, the estimated cost to build the powerhouse at the base of Qargha Dam would be $1,230,000. This number must be adjusted for the "Cost of Construction in Afghanistan." Subject to further investigation, there is the possibility that a 2000-m long penstock could be built, which might increase the head at the powerhouse to as much as 100 m. With a 100-m head, the average output from the generating station will be 103 kW. A penstock arrangement of this nature would probably eliminate some of the irrigation capability that currently exists. The estimated cost in the United States to build the penstock and the Powerhouse is $4,092,000. This number must be adjusted for the "Costs of Construction in Afghanistan'.

Obtaining the power outputs presented here will require a powerhouse capable of handling widely varying flow rates. It is expected that between 3 and 5 turbines, of varying sizes, will be required. If the power values presented here warrant additional and more detailed study, then the following next steps are recommended:

1. Determine if the Gauging Station downstream of Qargha Dam represents the outflow from Qargha reservoir. If it does not, then identify the reservoir outflow as a function of time (monthly variations).
2. Identify the irrigation water extraction points downstream of Qargha Dam. Identify the elevation drop between Qargha Reservoir and a point 2000 m downstream of the reservoir. Determine if a 2000-m penstock is viable.
3. Determine the seasonal variation of the elevation of Qargha Lake.

B.4 Contact information

Author

Charlie Allen, Chief, Turbomachinery Section, Hydroelectric Design Center
Phone: 503-808-4296
Cell: 503-816-3468
e-mail: charlie.allen@usace.army.mil

Hydroelectric Design Center Team Lead

Jeff Hurt, Chief, Product Coordination Branch, Hydroelectric Design Center
Phone: 503-808-4281
Cell: 503-961-3082
e-mail: jeff.s.hurt@usace.army.mil

Back-up Technical Support

Jim Kerr, Chief, Mechanical / Structural Branch, Hydroelectric Design Center
Phone: 503-808-4250
Cell: 503-961-5703
e-mail: James.D.Kerr@usace.army.mil

B.5 Hydropower basics

Before delving into the study, a brief overview of hydropower basics will be presented. This information is offered so that the user will understand how the calculations are performed, and why certain parameters are fundamental to obtaining good answers. The equation for calculating the amount of power available at a specific site is:

Power = Head x Flow x Efficiency x Constant

In Metric Units, this becomes

P = Head x Flow x E x C2

where:

P is the kW produced by the site
Head is measured in meters
Flow is measured in cubic meters per second (CMS)
E is the equipment efficiency, nominally 80 percent
C2 is a constant, in this equation equal to 9.79

The above equation assumes that the equipment operates at a constant efficiency, and that the water temperature is 20 °C. Neither of these assumptions is correct all the time, but the assumptions of constant efficiency and constant water temperature are sufficient for a reconnaissance study.

"Head" is the difference between the elevation at the top of the water in the reservoir (not the top of the dam, but the top of the water surface) and the elevation where the water discharges from the hydroelectric unit.

"Flow" is the flow rate—in CMS—of water through the hydroelectric unit.

It is apparent from the equation that two primary parameters impact the amount of power produced by a hydroelectric unit—the Head and the Flow. More power can be obtained by either increasing the head or increasing the flow. The other point is that power output is instantaneous, that is, it is a product of the head and flow in the system at the moment of generation. If a machine is sized to produce 100 KW at 90 m head and 0.14 CMS Flow, then reducing either the head or the flow will reduce the power produced by the generating unit.

B.6 Geography downstream of Qargha Dam

Figure B1 (copied from the Qargha Dam Assessment (13 April 2006) shows the terrain downstream of the Qargha Dam. Participants in the assessment were:

- Jim Dexter – IRD, Kabul
- Pir. M. Azizi - IRD, Kabul
- Nader Noori--IRD, Kabul
- Mrs. Suraia – Kabul Irrigation Department
- Aqa Shirin – Paghman Irrigation Department.

Figure B1. Terrain downstream of Qargha Dam.

The photograph shown in Figure B1 was taken from the top of Qargha Dam, and shows the downstream face of the dam in the foreground. Reasonable observations from the picture include:

- The primary water outlet from the dam is the irrigation canal.
- There is not a lot of “drop” in elevation of the water channel downstream of the dam. The canal is already at the bottom of the surrounding topography.
- The locations where the irrigation water is diverted from the canal are not apparent.

B.7 Source data for flow

Flow data were obtained from US Geological Survey (USGS) Scientific Investigations Report 2009-5262, *Conceptual Model of Water Resources in the Kabul Basin, Afghanistan* (T.J. Mack et al. 2009), also cited as USGS Afghanistan Project Product Number 168, and accessible through URL: http://pubs.usgs.gov/sir/2009/5262/pdf/sir2009-5262_front-text_508_Pt1_i-32.pdf

Table B1 lists outflow from the Qargha Reservoir; quantifying maximum, mean and minimum flow rates for each month.

Table B1. Outflow from the reservoir.

Month	Flow Rates, by Month (m^3/sec)		
	max	mean	min
Oct	0.60	0.24	0.07
Nov	0.36	0.15	0.06
Dec	0.34	0.10	0.03
Jan	0.28	0.08	0.02
Feb	0.31	0.09	0.02
Mar	0.32	0.10	0.03
April	0.42	0.13	0.05
May	0.88	0.12	0.12
June	0.97	0.20	0.20
July	0.54	0.14	0.14
Aug	0.62	0.14	0.14
Sept	0.68	0.10	0.10

The flow rates listed in Table B1 were taken from a gauging station downstream of Qargha Dam. The location of the gauging station (how far downstream) relative to the dam, and whether if the gauging station records the entire flow out of Qargha Reservoir, are unknown. In fact, whether this gauging station correctly measures the entire flow out of the reservoir is one of the largest uncertainties of this reconnaissance report.

B.8 Source data for head

The "Qargha Dam Assessment" states that the dam is 30-m high, and the water elevation above the bottom of the reservoir is 27.5 m. Another document provided by JPIO states that the water elevation above the bottom of the reservoir is 25 m (see Annex 1 to this Appendix). Considering the probability of seasonal variation, these two values are not inconsistent with each other.

Open source (Google Maps) topographical data indicate there might be as much as 100 m elevation difference between the top of the reservoir and a point 2000 m downstream of the dam. Figure B2 shows a topographic map of the Qargha reservoir and environs.

Figure B2. Topographic map showing Qargha reservoir and environs.

The extent to which the elevation of the Qargha Reservoir varies throughout the year is unknown. If the surface elevation varies substantially, then the power values calculated below will decrease.

B.9 Power available

Calculation of power output from a generating station installed at the base of the dam will be based on the following parameters:

- a Head of 25 m
- mean flow rates recorded by the gauging station downstream of Qargha Dam.

Table B2 lists the mean monthly power output of a generating station at the base of the dam for a head of 25 m and monthly mean flow rates.

B.10 Average monthly power output: 26 KW.

The power output listed in Table B2 is based on mean flow data, i.e., 50 percent of the time the flow exceeds the values, 50 percent of the time the flow is lower. This means that the calculated power outputs represent the energy (kWh) that can be generated from the site, assuming that every drop of water passes through the hydropower units. In other words, the power outputs identified above represent the average power that the powerhouse will be delivering each month, operating 24 hrs per day for the entire month.

Table B2. Results of 25-m head power calculations.

Month	Mean Flow rate (CMS)	Power Output (kW)
Oct	0.24	47
Nov	0.15	29
Dec	0.10	20
Jan	0.08	16
Feb	0.09	18
Mar	0.10	20
April	0.13	25
May	0.12	23
June	0.20	39
July	0.14	27
Aug	0.14	27
Sept	0.10	20

This means that the hydropower generating station needs to have equipment to efficiently accommodate both the maximum available flow (0.97 CMS during the month of June) and the minimum flow (0.02 CMS in January and February). To accommodate this broad range of flows, the generating station will probably require between 3 and 5 generating units, of different sizes. The number and sizing of the generating units can only be determined with a detailed study, including a far more detailed analysis of the flow data.

If it is possible to build a long penstock to take advantage of the small elevation drop of the basin downstream of Qargha Dam, assuming a 100 m head could be obtained and using the mean flow rates identified above. Table B3 lists the power output (in kW).

The power outputs listed in Table B3 assume that a 100 m head is available. Based on an interpretation of Google Maps topographic information, it will require a 2000 m long penstock to develop this amount of head. This also means that no irrigation water can be drawn off before the water passes through the powerhouse at the end of the penstock. While unconfirmed, it is highly probable there are irrigation “take-offs” that would be eliminated by the installation of such a penstock. Figure B3 shows potential penstock overlaid on a satellite photo of the Qargha reservoir.

Table B3. Results of 100 m head power calculations.

Month	Mean Flow rate (CMS)	Power Output (KW)
Oct	0.24	188
Nov	0.15	117
Dec	0.10	78
Jan	0.08	63
Feb	0.09	70
Mar	0.10	78
April	0.13	102
May	0.12	94
June	0.20	157
July	0.14	110
Aug	0.14	110
Sept	0.10	78
Average Monthly Power Output: 103 KW		

Figure B3. Potential penstock overlaid on satellite photo.

B.11 Estimated costs

Costs listed in Table B4 are for equipment delivered from a forward operating base (FOB) factory location in the United States, and represent the costs for construction in the United States. Costs for this work to be performed in Afghanistan, and for equipment shipment to Afghanistan, must be determined by those familiar with the costs and the complications of the local environment.

Table B4. Costs for equipment delivered FOB factory location in the United States (which represent the costs for construction in the United States).

Cost	Type of Cost	Cost for Work Performed in United States
For the 26 KW Powerhouse at the Base of the Dam		
Equipment Cost	Initial Construction	$1,000,000
Building Cost Including short coupled penstock	Initial Construction	$230,000
Annual O&M, excluding labor	Annual Expense	$10,000
O&M Labor, 4 Full Time Employees	Annual Expense	Unknown
For the 103 KW Powerhouse at the end of a 2000-m penstock		
Equipment Cost	Initial Construction	$1,200,000
Building Cost	Initial Construction	$192,500
Penstock Cost	Initial Construction	$2,700,000
Annual O&M, excluding labor	Annual Expense	$10,000
O&M Labor, 4 Full Time Employees	Annual Expense	Unknown

The equipment package assumes three turbine / generators of differing sizes to accommodate the large flow variations. Price quotations were obtained from Canyon Industries of Deming, WA. Canyon Industries specializes in the manufacture of small turbine/generator packages of the type that would be used at Qargha Dam.

The Powerhouse is assumed to be a 24 x 61 ft pre-fabricated metal pole building with a slab-on-grade foundation. The cost development for the building is shown in Annex 2 to this Appendix.

The cost estimate for the 2000-m penstock is based on a buried 36-in. diameter penstock. Details of the price development are presented in Annex 3 to this Appendix.

Annex 1: Data Received from JPIO

Power Potential		
Hd=	24.85	m
Qd=	0.5	cms
nd=	0.7	efficiency
Pd=	85.23	kw
	85,234	w
Assume residential power supply requirements are		
	350	w
Number residences served	244	

Units of Power Measurement

When U.S. customary units are used:

$$P_d = 0.1134\ Q_d h_d \eta_d$$

where

P_d = turbine output, horsepower (1 hp = 550 ft·lb/s),
Q_d = full-gate discharge (at h_d), ft³/s,
h_d = design head, feet, and
η_d = design efficiency, percent.

When metric units are used, power will be expressed in metric horsepower or kilowatts, and:

$$P_d = 13.35\ Q_d h_d \eta_d$$

where

P_d = turbine output, horsepower (1 hp = 75 m·kg/s),
Q_d = full-gate discharge (at h_d), m³/s,
h_d = design head, metres, and
η_d = design efficiency, percent,

or

$$P_d = 9.804\ Q_d h_d \eta_d$$

where

P_d = turbine output, kilowatts (1 kw = 101.971 m·kg/s),
Q_d = full-gate discharge (at h_d), m³/s,
h_d = design head, metres, and
η_d = design efficiency, percent.

Note:

n_s, metric hp units = 4.45 n_s, U.S. customary hp units
n_s, kilowatt units = 3.81 n_s, U.S. customary hp units
n_s, kilowatt units = 0.86 n_s, metric hp units

$$n_s = \frac{n(P_d)^{1/2}}{(h_d)^{5/4}}$$

n = rotational speed, r/min

η_d = design efficiency, percent

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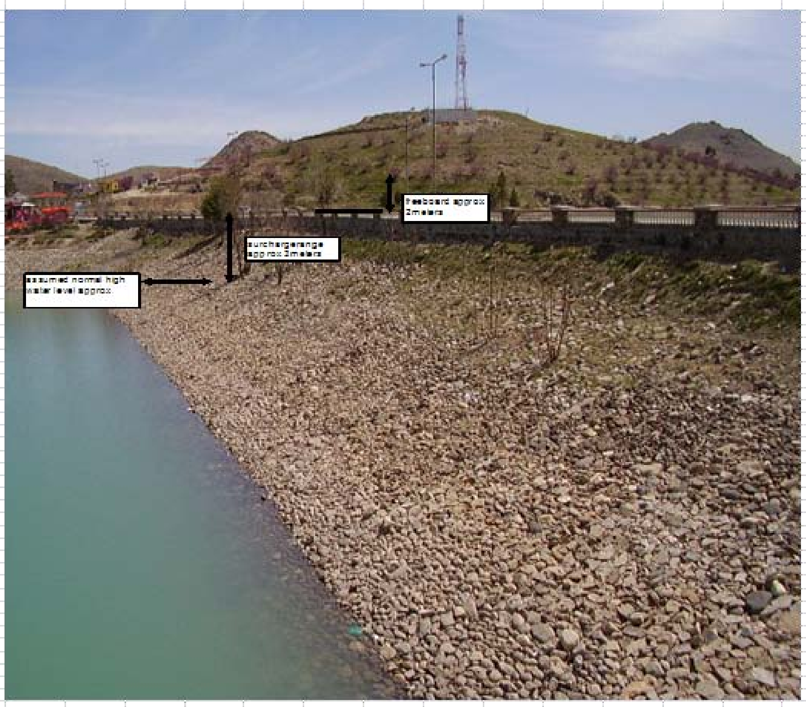
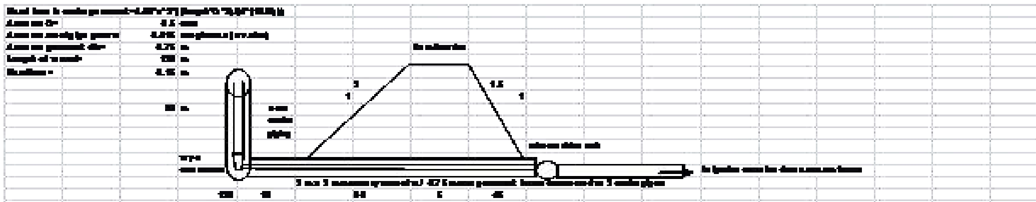
U.S. GOVERNMENT PRINTING OFFICE: 1976 O—599-976

[illegible]	[illegible]	m
Dam Height	[illegible]	m
Free board plus surcharge range	5	m
Normal pool head	25	m





Annex 2: Generator Building Cost Estimate

Generator Building Cost Estimate Christensen, NWP
19 July 2010

Assumptions as follows (very rough estimate):

Generator Building

- Min Foundation Foot Print: 24 feet by 61 Feet
- Foundation: Slab on grade (slab will be design for moving generators for maintenance)
- Building: Pre-Fab Metal Pole Building Kit
- Doors: 3 - 10 feet wide by 12 feet high roller doors centered on generators. 2- 4 feet by 6 feet 8 inch HD man doors (each side of building).
- Windows: 3 – 4 feet by 6 feet thermo-pane
- Lighting: Fluorescent Shop Lights (8)
- Exterior Lights (4)
- Electrical: 200-amp Service
- No Air-conditioning or Sewer Service
- 3: Formed wet well discharge areas under each Turbine for discharge back to irrigation canal

Penstock

- 200 feet of 36-inch RCP penstock from dam to new powerhouse

Engineer's Estimate (US $ Construction, Transport costs not included)

ITEM	Quantity	Unit	Unit Cost ($US)	Total
• Mob and Demob	1	Job	10,000	10,000
• Foundation grading	1	Job	2,500	2,500
• Leveling gravel	CY	105	20	2,100
• Reinf. Concrete (including wet wells)	CY	120	200	24,000
• Pre-Fab Building Kit	1	Job	50,000	50,000
• 10 x 12 Steel Roller Doors	3	Each	5,000	15,000
• 4 x 6-8 Steel Man Doors	2	Each	1,000	2,000
• 4 x 6 Thermo-pane Widows	3	Each	500	1,500
• 8 feet 2-Tube Fluorescent Lights	8	Each	100	800
• Exterior Lights (Building Corners)	4	Each	100	400
• 200 Amp Electrical Panel	1	Each	250	250
• Electrical Work (Outlets, Switches, etc.)	1	Job	5,000	5,000
• Foundation Prep Penstock	1	Job	2,500	2,500
• RCP (Penstock)	200	LF	125	37,500
SUBTOTAL			**$ 153,500**	
Contingency (50%)			**76,750**	
TOTAL			**$ 230,250**	

Annex 3: Price Estimation for Construction of 2000-M Penstock

Costs are taken from RS Means 2010 and are listed in US dollars.

Costs assume:

- 2000 m of steel pipe installed in 8-ft deep trench excavated in common earth materials.
- Ground line survey of alignment
- Backhoe pit explorations to depth at 200 m intervals along alignment.

Costs:

Line Survey	2000 lineal meters @ $5.88/m =	$11,545
Explorations	10 backhoe pits to 9 2.5 m deep =	$5000
Steel Pipe	2000 lineal meters of 3-ft diameter installed @ $1302/m =	$2,604,000
Total Cost (US$):		$ 2,620,545 (rounded to $2,700,000)

Appendix C: Energy Conservation Technologies

C.1 Energy-efficient lighting and fixtures

C.1.1 Lighting

ENERGY STAR qualified light bulbs (for standard fixtures) use about 75 percent less energy than standard incandescent bulbs, generate 75 percent less heat, and last up to 10 times longer. Bulbs are available in different sizes and shapes to fit in almost any fixture. ENERGY STAR qualified fixtures are designed to optimize the performance of the enclosed efficient light source.

C.1.2 Fixtures in public spaces

- Use T8 lamps. T5's are not recommended at this time. Replacement lamps and ballasts for T8's would be much more widespread in the area than the T5's. Also, energy savings is not that much between the two sizes.
- Consider daylighting
- Use LED Exit Signs
- For outdoor use:
  - Where color rendition is an issue, use metal halide.
  - Where color rendition <u>is not</u> an issue, use high pressure sodium.

C.1.3 Lighting controls/sensors

Lighting controls should be carefully selected to ensure optimum performance and compatibility with light fixtures, and to maximize payback. Frequent switching of high efficacy sources, particularly compact fluorescent lighting sources (pin-based fluorescent or screw base Compact Fluorescent Lamp [CFL]) will lead to reduced lamp life, increasing lamp replacement costs. Therefore, sensors are best selected for spaces where lighting is likely to be operated for at least 15 minutes at a time. Public spaces such as meeting rooms, where lighting may continue to operate long after occupants have left the room, are ideal locations for installation of sensors. The preferred type of occupancy sensor requires manual activation with an automated off function; some manufacturers refer to this subset of sensors as vacancy sensors. Vacancy sensors may ensure that light-

ing is not activated when not needed, for example in a sun-lit room. Sensors should employ a mechanical air-gap relay.

C.2 Programmable thermostats

Install programmable thermostats. Occupants with dedicated heating and cooling systems can save about 20 percent annually by properly setting their programmable thermostats and maintaining those settings.

C.3 Water efficiency

- Install WaterSense labeled toilets (less than 1.28 gal/flush).
  For a list of WaterSense labeled high efficiency toilets (HETs), see:
  http://www.epa.gov/watersense/pp/find_het.htm
- Install WaterSense labeled faucets or accessories (less than 1.5 gal/minute). For a list of WaterSense labeled faucets/accessories, see:
  http://www.epa.gov/watersense/pp/lists/find_faucet.htm
- Install low-flow showerheads (less than 2.2 gal per minute).

C.4 Ductwork sealing and insulation

- Verify that forced air systems, where installed, are operating within the manufacturer's specifications for airflow (cfm/ton for air conditioners, within heat rise limits for furnaces) before and after duct sealing.
- Seal all duct joints with airtight collars, mastic, and/or UL-181 tape.
- Insulate all ductwork located in unconditioned space to at least R-6.
- Insulate all accessible ductwork located in conditioned space to at least R-6, especially in places where condensation is a problem.

C.5 Envelope sealing and insulation

C.5.1 Envelope Improvements

- Seal air leaks using materials (low volatile organic compound [VOC] if available) that meet fire code requirements:
  - to attic spaces or into basements; include sill and top plates
  - along the top, bottom, or inside party walls
  - around windows and doors
  - around access to common stair wells around plumbing, electrical, or ventilation shafts

- around any vents, flues, chimneys that penetrate the roof or side walls
- around decks, balconies, or cantilevers.

- Install exterior shades to reduce radiant heat load in summer while allowing sunlight in the winter.
- Wherever air sealing is installed, upgrade ventilation fans to Energy Star and consider improved controls to maintain adequate air exchange (refer to Ventilation specifications).
- Do not add insulation to existing attic spaces without first verifying that an effective air barrier exists between the attic and the living space using the procedures described in the Building Performance Institute's Technical Standards for Building Analysts.
http://www.bpi.org/documents/Shell_Standards.pdf
- Air sealing measures should be installed and prioritized using the procedures described in Building Performance Institute's Technical Standards for Shell Specialists: http://www.bpi.org/documents/Shell_Standards.pdf
- Consider a pre-installation blower door test to identify air leaks that need to be sealed. A post-installation blower door test will ensure that the leaks have been sealed and there continues to be adequate ventilation. Units in excess of maximum allowable air exchange rates as determined by American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 119 shall be sealed to reduce air leakage through the building envelope. Ventilation systems must be installed and/or modified as necessary to ensure compliance with ASHRAE Standards 119 and 62.2 based on final blower door numbers.
- Consider earth-protected space: Bermed, or partially buried, construction can moderate building temperature, save energy, and preserve open space and views above the building
- A pre-installation combustion test may help determine whether the building has health or safety issues.
- A combustion safety test on combustion equipment when air sealing has been performed is highly recommended.

C.5.2 Recommended insulation levels for buildings

Climate Zone	Add Insulation to Attic: Uninsulated Attic	Add Insulation to Attic: Existing 3–4 in. of insulation	Floor over Crawl l Space or Unconditioned Basement	Conditioned Basement Wall or Slab	Wall Construction
5 to 8 (Kabul, Afghanistan)	R49 to R60	Up to additional 12–18 in. of insulation	R30 to R38	R19 or more	Consider designing and building the facility by doubling the thickness of the original wall design

C.6 Ventilation (ductwork sealing and insulation) upgrades

- At a minimum, seal around register boots at the boot/wall and/or boot/ceiling connection at each exhaust and supply register using rated products (mastic and/or tape as appropriate).
- More advanced upgrades include:
  - Seal all joints in ventilation ductwork using approved method.
  - Install airflow regulators or other control system on central ventilation stacks
  - Replace all fans with high efficiency and/or variable frequency drives
  - Install timers on roof fans per code
  - Air seal central ventilation stacks
  - Control exhaust ventilation fans in public garages connected to occupied spaces with carbon monoxide detection device(s).

C.7 Energy management system

Install timer controls with properly set year-round clocks for boilers providing central heating. Properly set timers should adjust heat levels to respond to seasonal and time of day heating requirements. Install outdoor reset controls set for automatic shutdown at 55 °F in warm weather and at 45 °F at night.

C.8 HVAC (climate specific recommendations; specifications for individual unit heating and cooling)

<table>
<tr><th>Equipment</th><th>Hot Climates (Climate Zones 1, 2, 3)
(Southern Afghanistan)</th><th>Mixed and Cold Climates (Climate Zones 4, 5, 6, 7, 8)
(Kabul, Afghanistan)</th></tr>
<tr><td>Cooling</td><td>Right Sized:*
ENERGY STAR qualified A/C; <u>OR</u>
ENERGY STAR qualified Heat Pump</td><td>Right Sized:*
• ENERGY STAR qualified A/C; <u>OR</u>
• ENERGY STAR qualified Heat Pump</td></tr>
<tr><td rowspan="2">Heating</td><td>ENERGY STAR qualified heat pump, OR
80 annual fuel utilization efficiency (AFUE) boiler, OR
80 AFUE oil furnace</td><td>ENERGY STAR qualified heat pump; OR
ENERGY STAR qualified boiler; OR
ENERGY STAR qualified oil furnace
For central boilers, where possible, replace modular boiler sets with full-sized dual boilers (for redundancy) with fully modulating burners**
Controls:
• Hydronic Systems: install night set-back and thermostatic terminal controls
• District hot water or steam systems: Install night setback, thermostatic radiator valves, and outdoor reset for vacuum steam</td></tr>
<tr><td colspan="2">Radiant Floor Heating:
Consists of a network of pipes uniformly scattered and buried under the floor with hot water used as the heating medium. The water is heated via the solar water heater.
Heating System Upgrades
• Boiler systems: Insulate condensate tank, Insulate steam and hot water piping
• Minimize or eliminate the dependence on resistance heating: replace with heat pumps</td></tr>
<tr><td>Air Handler</td><td colspan="2">Consult with HVAC vendor to consider:
• air handler blower motor with ECM motor, or
• blower/motor with more efficient air handling design.
Seal air handler cabinet joints to prevent “short-circuiting” of air flow</td></tr>
<tr><td colspan="3">* “Right-sizing” must be done with consideration for the existing distribution system, or in tandem with a new distribution system. Cooling equipment shall be sized according to the latest editions of ACCA Manuals J and S, ASHRAE Handbook of Fundamentals, or an equivalent procedure. Maximum oversizing limit for air conditioners and heat pumps is 15% (with the exception of heat pumps in Climate Zones 5 - 8, where the maximum oversizing limit is 25%). In addition, indoor and outdoor coils shall be matched in accordance with ARI standards.
** A central furnace or boiler’s efficiency is measured by annual fuel utilization efficiency (AFUE). AFUE is a measure of how efficient the appliance is in the energy in its fuel over the course of a typical year.</td></tr>
</table>

C.9 Water heater

Consider a heat pump water heater if you:

- are willing to pay more upfront
- have space to accommodate a condensate drain
- use waste heat exhaust from the nearby diesel generators.

C.10 Site design and building orientation

To implement “passive” energy conservation measures:

- Minimize east and west glass.
- Consider connecting buildings where practical.
- Establish building on an east-west axis if possible.
- Consider seasonal variations in wind speed and direction.
- Establish floor grades that least impact site grading.

C.11 Energy-efficient replacement windows, doors, and skylights

Windows & Doors

Climate Zone	U-Factor[1]	SHGC[2]	
Northern	≤ 0.35	Any	
North/Central	≤ 0.40	≤ 0.55	
South/Central	≤ 0.40	≤ 0.40	Prescriptive
	≤ 0.41	≤ 0.36	Equivalent Performance *(Excluding CA)*
	≤ 0.42	≤ 0.31	
	≤ 0.43	≤ 0.24	*Products meeting these criteria also qualify in the Southern zone.*
Southern	≤ 0.65	≤ 0.40	Prescriptive
	≤ 0.66	≤ 0.39	Equivalent Performance
	≤ 0.67		
	≤ 0.68	≤ 0.38	
	≤ 0.69	≤ 0.37	
	≤ 0.70		
	≤ 0.71	≤ 0.36	
	≤ 0.72	≤ 0.35	
	≤ 0.73		
	≤ 0.74	≤ 0.34	
	≤ 0.75	≤ 0.33	

Skylights

Climate Zone	U-Factor[1]		SHGC[2]
	2001 NFRC rated at 20°[3]	*RES97 rated at 90°[4]*	
Northern	≤ 0.60	≤ 0.45	Any
North/Central	≤ 0.60	≤ 0.45	≤ 0.40
South/Central	≤ 0.60	≤ 0.45	≤ 0.40
Southern	≤ 0.75	≤ 0.75	≤ 0.40

[1] *Btu/h.ft². °F*

[2] *Fraction of incident solar radiation.*

[3] *U-Factor qualification criteria based on 2001 NFRC simulation and certification procedures that rate skylights at a 20-degree angle. Although reported U-Factor is higher than RES97 rated products, energy performance at the ENERGY STAR minimum qualifying level is equivalent.*

[4] *NFRC certification using the 1997 NFRC procedures for residential windows (RES 97) that rated skylights at a 90-degree angle. Skylights rated under this procedure may be present in the marketplace until March 31, 2008. NFRC labels for products using this procedure state: "RES97 rated at 90 degrees."*

1 The rate of heat loss is indicated in terms of the U-factor (U-value) of a window assembly. The lower the U-value, the greater a window's resistance to heat flow and the better its insulating value.
2 The SHGC is the fraction of incident solar radiation admitted through a window, both admitted through a window, both directly transmitted, and absorbed and subsequently released inward. SHGC is expressed as a number between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits.
3 Add window-film or glazing
4 Add an external shading device
Note: Afghanistan considered "Northern" for analysis

C.12 Energy-efficient replacement motors and pumps

Motors and Pump 1 hp or greater should meet the standards of the National Electrical Manufacturers Association (NEMA) for premium efficiency. Product scope and nominal efficiency levels for the NEMA Premium program can be found at:

http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf

C.13 Building management system

Building controls, including building management and automation systems, are intended to optimize the performance of the building's subsystems. Controls use computer-based monitoring to optimize building control subsystems such as:

- Heating, Ventilation, and Air Conditioning (HVAC)
- Fire
- Electrical monitoring/management
- Lighting
- Security and closed circuit TV
- Life safety
- Access control

Although good energy management systems can reduce annual energy consumption by 10–35 percent, trained personnel will be required to operate and maintain such systems.

Appendix D: Emerging Renewable Energy Technologies (not commercially available)

D.1 Non-commercially available renewable energy technologies

While certain commercial alternative technologies have been designated as either feasible or unfeasible for the ANSU site, this certainly does not mean that the complex is limited to those cited. Alternative energy sources that may help prove beneficial in the near future are continuously being researched, innovated, and improved for greater efficiency. In addition to the technologies already proven viable for the ANSU site, other technologies (not yet commercialized for use) have potential for the site. Such non-commercialized technologies include: cellulosic ethanol, enhanced geothermal systems, nanotechnology thin-film solar panels, wind-to-hydrogen systems, aerogels, fuel cells, and a combined PV solar air and heat pump.

D.1.1 Cellulosic ethanol

Source: Environmental and Energy Study Institute (EESI). 2007. "Cellulosic Ethanol: Not Just Any Liquid Fuel." Briefing. EESI: Washington, DC, http://www.eesi.org/021207_Cellulosic_Ethanol.

Cellulosic ethanol is a biofuel that is produced from wood, grasses, and/or non-edible parts of plants. The production of the biofuel comes from lignocelluloses, which is a structural material that is made up of mostly of cellulose, hemicelluloses, and lignin. The production of ethanol requires a large amount of processing time to make the sugar monomers available to produce ethanol from fermentation. The most widely used process cellulolysis, which consists of hydrolysis on pretreated lignocellulosic materials. The use of enzymes and simple sugars breaks down the complex cellulose, which is then followed by fermentation and distillation. The cellulolysis process is broken up into six stages: (1) pretreatment, (2) cellulytic process, (3) separation of sugars, (4) microbial fermentation, (5) distillation, and (6) dehydration.

Instead of taking the grain from wheat and grinding it down to starch and gluten, cellulosic ethanol production involves the use of the whole crop. This approach should increase yields and reduce the carbon footprint be-

cause the amount of energy-intensive fertilizers and fungicides remains the same, yet the output of usable material is higher.

Cellulosic ethanol has the potential to become a competitive energy resource, but requires additional financial support to develop the infrastructure necessary for the technology. This technology would be ready for commercial purchase and use in the next 4 to 5 yrs.

D.1.2 Nanotechnology

Source: *Montreal Gazette*. 2010. "Future of solar energy continues to brighten," http://www.montrealgazette.com/technology/Future+solar+energy+continues+brighten/3656156/story.html

Solar power costs are already much lower than in the recent past. With new development in nanotechnology scientists have published research that promises to increase the output while reducing costs. Ultra-thin solar cells can absorb sunlight more efficiently than the silicon cells used today, which are thicker and more expensive to manufacture. This is due to the different behaviors examined at the nanometer (1.0×10^{-9} m). Researchers calculate that, by properly configuring the thicknesses of several thin layers of films, an organic polymer could absorb as much as 10 times more energy than its silicon counterpart. Nanoscale solar cells also offer savings in material costs, as the organic polymer thin films and other materials used are less expensive than silicon. Nanotechnology for PVs at the ANSU site could easily be replaced at a lower cost while producing a higher output than previously thought.

This technology is rapidly advancing. It is anticipated that nanotechnology integrated into PV arrays will be commercially available by 2011.

D.1.3 Aerogels

Source: Aerogel. 2005. "AeroGel – History, Characteristics, Properties and Applications," http://aerogel.nmcnetlink.com/.

An aerogel is a material with the lowest bulk density of any known porous solid. It comes from a gel in which the liquid component of the gel has been replaced with a gas. This produces an extremely low-density solid, while being a great thermal insulator. Aerogels are produced by extracting the liquid of a gel through supercritical drying. This allows the liquid to be slowly drawn off without causing the solid matrix to collapse. Aerogels have been used to add insulation. Aerogels could be easily added to the ANSU complex to provide better energy efficiency for all the buildings.

Aerogels are good thermal insulators because they nullify the three methods of heat transfer (convection, conduction, and radiation). Aerogels are good conductive insulators because they are composed primarily from gas, which are naturally very poor heat conductors.

D.1.4 Wind-to-hydrogen systems

Source: PhysOrg.com. 2010. "Experimental 'wind to hydrogen' system up and running," http://www.physorg.com/news87494382.html.

One of the key issues with wind energy is its intermittent nature. Intermittency is a problem related to the ability to match the generated supply of electricity to actual demand. This has led to numerous methods of storing energy including the production of hydrogen through the electrolysis of water. This hydrogen is subsequently used to generate electricity during periods when demand cannot be matched by wind alone. The energy in the stored hydrogen can be converted into electrical power through fuel cell technology or a combustion engine linked to an electrical generator. With the potential of adding wind power to the ANSU site, this new power system could be used to enhance productivity and control the intermittent problem.

Wind-to-hydrogen systems are still a fairly new idea, and is still under a lot of research at the National Renewable Energy Laboratory (NREL). The hybrid is making a lot of promise and may be released for commercial use in the near future.

D.1.5 Combined PV and heat pump

Source: Zondag, Dr. H.A. "Combined PV-air collector as heat pump air preheater," Netherlands Energy Research Foundation ECN, Petten, The Netherlands, http://www.builditsolar.com/Projects/rx02065.pdf.

A PV-panel produces not only electricity, but heat from the sun as well. Roughly 20 percent of solar radiation is reflected and 15 percent is converted to electricity, which implies that 65 percent goes to heat production in the PV laminate. The hot PV panels can be cooled by an air flow. This lowers the PV temperature (which increases PV performance) and provides hot air that can be used as a source of heat for a heat pump. Air drawn through rectangular channels beneath the PV is then guided to the evaporator of a heat pump boiler. This heat pump boiler not only withdraws heat from the channels underneath the PV, but also from the emitted ventilation air. The airflow from underneath the PV is controlled by

adjusting the valves manually. The heat can be drained off and will contribute to the energy demand of a heat pump.

Combined PV and Heat Pump systems are still immature technologies that will not be ready for commercial purchase in the near future.

D.1.6 EGS

Source: Department of Energy (DOE). 2006. Geothermal Technologies Program: How an Enhanced Geothermal System Works. USDOE, Energy Efficiency and Renewable Energy, http://www1.eere.energy.gov/geothermal/egs_animation.html.

Enhanced Geothermal Systems (EGS) is a new type of geothermal power that does not require natural convective hydrothermal resources. EGS technologies create geothermal resources in the hot dry rock through hydraulic stimulation. EGS considers the possibility that natural cracks and pores on the earth's surface may not allow for flow rates. Through the use of hydraulic stimulation, high pressure cold water is injected into those pores that increase the fluid pressure enhancing the permeability of the fracture system. Additionally, the water that is injected into the system captures the heat from the rock and is forced out of a borehole as extremely hot war, which can then be converted to electricity using a steam turbine. MIT has reported that EGS could be capable of producing electricity for as low as 3.9 cents/kWh. There are four factors to consider:
(1) temperature of the resource, (2) fluid flow through the system,
(3) drilling costs, and (4) power conversion efficiency.

This technology is not expected to be ready for commercial purchase and use until 2050.

D.1.7 Fuel Cells

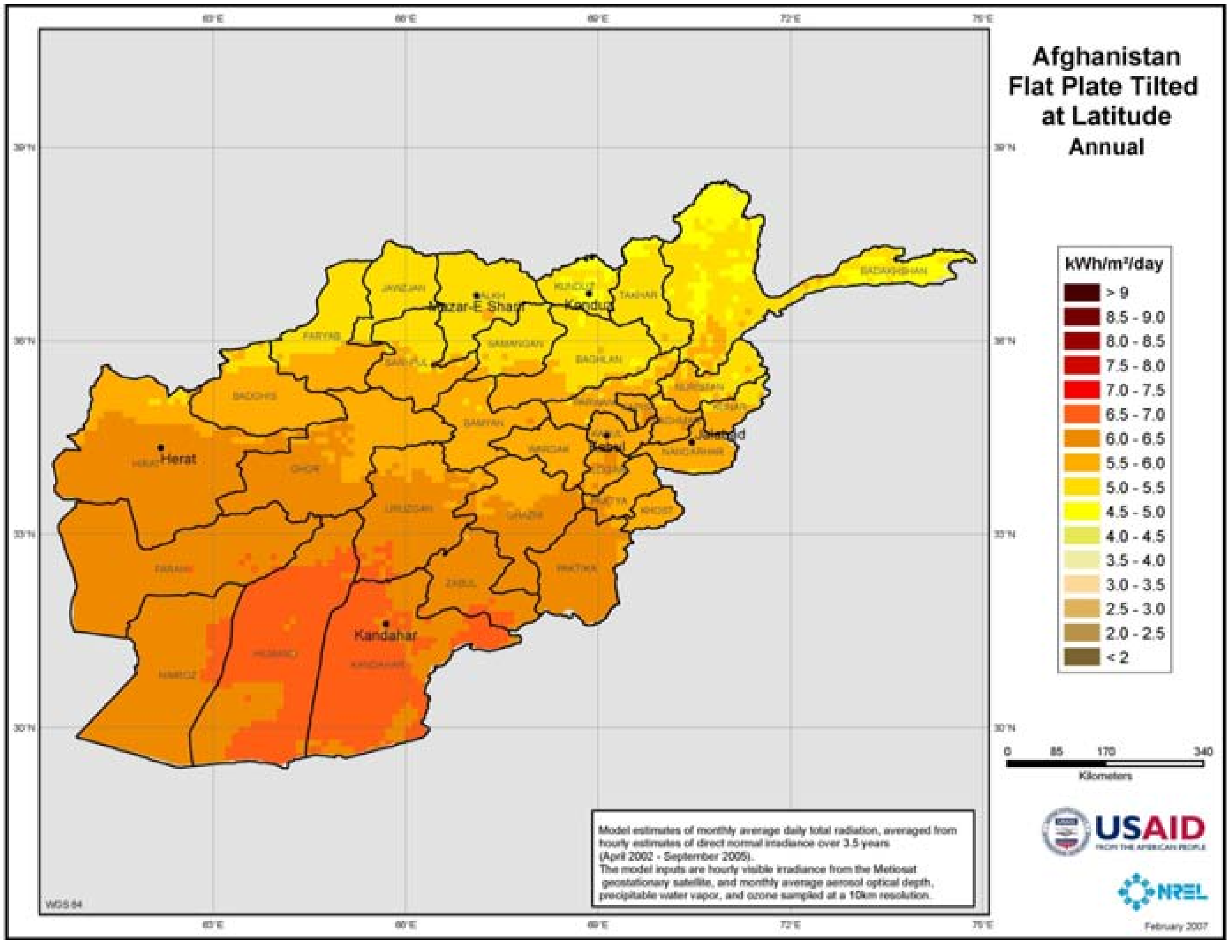
Source: Alternative Energy. "Fuel Cells," http://www.altenergy.org/renewables/fuel_cells.html.

A fuel cell is an electrochemical energy conversion device that converts hydrogen and oxygen into electricity, heat, and water. It is very much like a battery that can produce electricity while being recharged continuously. Fuel cells run on pure hydrogen, which makes them pollution free; they produce water, heat, and electricity. This technology has great potential to provide zero emissions and a decrease in pollution. Since there is virtually no combustion in a fuel cell, fuel is converted to electricity more efficiently than any other electrical generating technology available today. Economically, fuel cells represent a prudent path to provide the country's electric

power because they can be installed quickly, are fuel flexible, and can be put in place incrementally, mitigating the need for more costly changes. The major disadvantages to fuels cells are their size and high cost to manufacture. Furthermore, there is also no hydrogen infrastructure to supply hydrogen fuel.

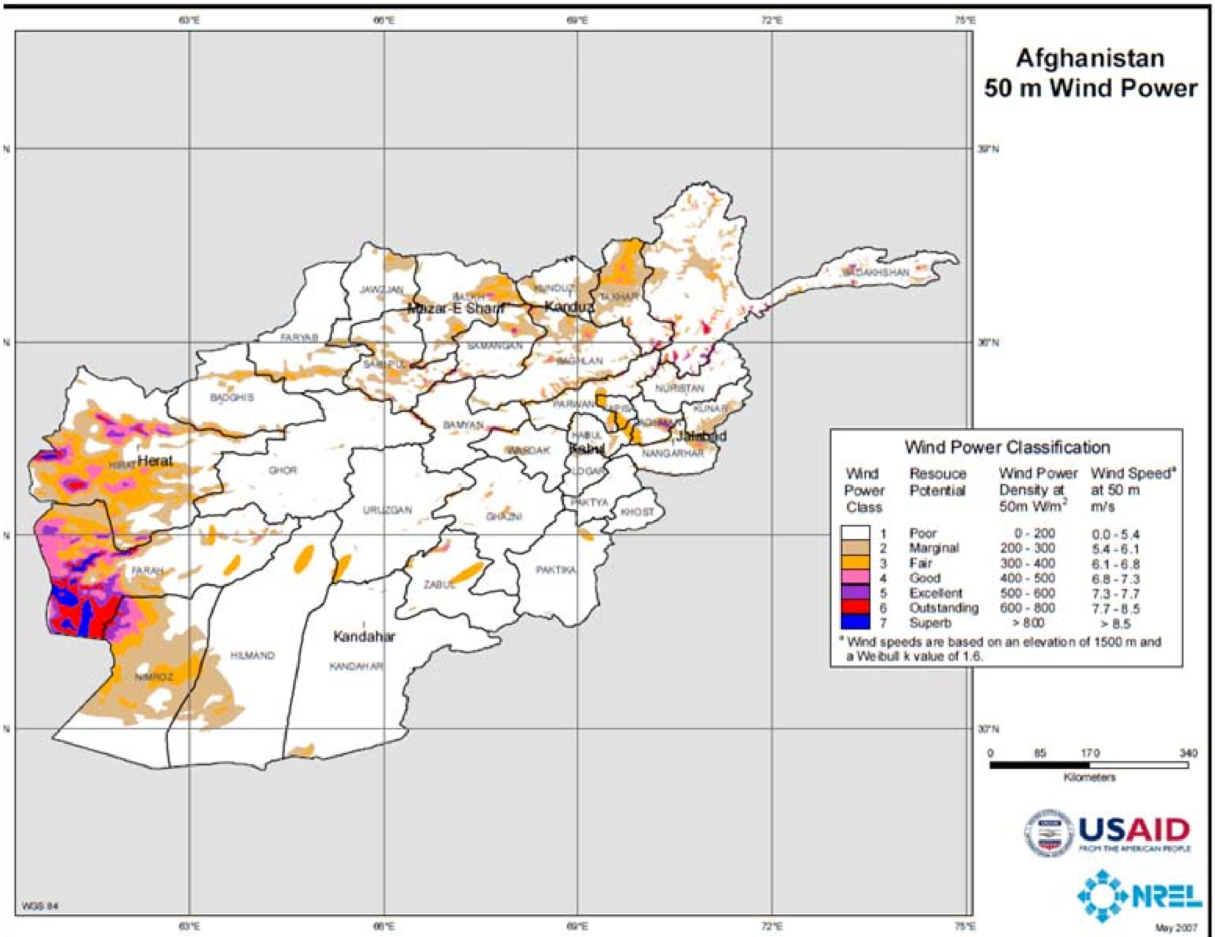
Fuel cells have been commercialized since 1959. However they are highly specialized and require extensive maintenance.

Appendix E: Solar and Wind Maps of Afghanistan



Source: National Renewable Energy Laboratory (NREL). 2009. International Activities: Afghanistan Resource Maps and Toolkit, http://www.nrel.gov/international/ra_afghanistan.html.

Figure E1. NREL solar map of Afghanistan.



Source: National Renewable Energy Laboratory (NREL). 2009. International Activities: Afghanistan Resource Maps and Toolkit, http://www.nrel.gov/international/ra_afghanistan.html.

Figure E2. NREL wind map of Afghanistan.

Appendix F: SolarWall™ Feasibility Analyses

F.1 SolarWall™ - Auditorium

RETScreen® Energy Model - Solar Air Heating Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		ADU Site	See Online Manual
Project location		Kabul, AFGN	
Nearest location for weather data		Kabul, AFGN	Complete SR sheet
Annual solar radiation (tilted surface)	MWh/m²	1.24	
Annual average temperature	°C	6.3	
Annual average wind speed	m/s	6.1	

System Characteristics		Estimate	Notes/Range
Heating application type	-	Ventilation air	
Base Case Heating System			
Heating fuel type	-	Diesel (#2 oil) - gal	
Heating system seasonal efficiency	%	75%	0% to 350%
Building			
Building type	-	Industrial	
Indoor temperature	°C	21.0	20.0 to 25.0
Minimum delivered air temperature	°C	18.5	
Maximum delivered air temperature	°C	40.0	
Building temperature stratification	°C	2.5	0.0 to 15.0
Floor area served by solar collector	m²	19,642	
RSI-value of ceiling	m² - °C/W	3.5	0.1 to 10.0
RSI-value of building wall	m² - °C/W	2.1	0.1 to 10.0
Airflow Requirements			
Design airflow rate	m³/h	45,000	50 to 1,000,000
Operating days per week (weekday)	d/w	5.0	0.0 to 5.0
Operating hours per day (weekday)	h/d	24.0	5.0 to 24.0
Operating days per week (weekend)	d/w	2.0	0.0 to 2.0
Operating hours per day (weekend)	h/d	24.0	5.0 to 24.0
Solar Collector			
Design objective	-	High temperature rise	
Collector colour	-	Black	See Product Database
Solar absorptivity	-	0.94	0.20 to 0.99
Suggested solar collector area	m²	1,250	
Solar collector area	m²	1,288	
Percent shading during season of use	%	0%	0% to 50%
SAH fan flow rate	m³/h/m²	35	
Average solar collector flow rate	m³/h/m²	19.6	
Average air temperature rise	°C	14.1	
Incremental fan power	W/m²	5.0	0.0 to 7.0

Annual Energy Production (9.0 months analysed)		Estimate	Notes/Range
Incremental fan energy	MWh	**42.2**	
Specific yield	kWh/m²	589	
Collector efficiency	%	35%	
Solar availability while operating	%	78%	
Renewable energy collected	MWh	441.4	
Building heat loss recaptured	MWh	59.1	
Destratification savings	MWh	257.8	
Renewable energy delivered	MWh	**758.3**	
	million Btu	2,587.2	
			Complete Cost Analysis sheet

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RETScreen® Solar Resource - Solar Air Heating Project

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Kabul, AFGN	See Weather Database
Latitude of project location	°N	35.5	-90.0 to 90.0
Slope of solar collector	°	90.0	0.0 to 90.0
Azimuth of solar collector	°	20.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector (kWh/m²/d)
January	1.00	2.29	-6.3	6.2	3.66
February	1.00	2.83	-4.9	6.1	3.60
March	1.00	3.86	-0.2	6.2	3.00
April	1.00	5.06	5.7	6.4	2.92
May	1.00	6.38	11.1	5.8	2.81
June	0.00	7.40	16.2	5.9	2.76
July	0.00	7.30	18.6	5.7	2.88
August	0.00	6.67	17.4	5.7	3.37
September	1.00	5.66	12.7	6.0	4.03
October	1.00	4.23	6.6	7.0	4.27
November	1.00	2.95	2.0	6.6	4.04
December	1.00	2.17	-3.2	6.1	3.55

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.73	1.08
Solar radiation (tilted surface)	MWh/m²	1.24	0.97
Average temperature	°C	6.3	2.6
Average wind speed	m/s	6.1	6.3

Return to Energy Model sheet

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RETScreen® Cost Analysis - Solar Air Heating Project

Type of analysis: Pre-feasibility | Currency: $ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Other - Feasibility study	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Development							
Other - Development	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Engineering							
Other - Engineering	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Energy Equipment							
Solar collector materials	m^2	1,288	$ 90	$ 115,920		-	-
Equipment installation	m^2	1,288	$ 50	$ 64,400		-	-
Cladding material credit	m^2	-1,288	$ -	$ -		-	-
Cladding labour credit	m^2	-1,288	$ -	$ -		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Energy Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 180,320	67.5%		
Balance of Equipment							
Fans and ducting materials	m^3/h	45,000	$ 1.40	$ 63,000		-	-
Fans and ducting labour	m^3/h	45,000	$ 1.00	$ 45,000		-	-
Fan and duct material credit	m^3/h	-45,000	$ 1.00	$ (45,000)		-	-
Fan and duct labour credit	m^3/h	-45,000	$ 0.50	$ (22,500)		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Balance of Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 40,500	15.2%		
Miscellaneous							
Overhead	%	10%	$ 220,820	$ 22,082		-	-
Training	p-h	0	$ -	$ -		-	-
Contingencies	%	10%	$ 242,902	$ 24,290		-	-
Sub-total :				$ 46,372	17.4%		
Initial Costs - Total				$ 267,192	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/insurance	project	0	$ -	$ -		-	-
O&M labour	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ -	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 220,820	$ -		-	-
Sub-total :				$ -			
Fuel/Electricity	kWh	42,195	$ -	$ -		-	-
Annual Costs - Total				$ -			

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
				$ -	-	-
				$ -	-	-
				$ -	-	-
End of project life		-		$ -		

Go to GHG Analysis sheet

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RETScreen® Financial Summary - Solar Air Heating Project

Annual Energy Balance

Project name		ADU Site	Electricity required	MWh	42.2
Project location		Kabul, AFGN			
Renewable energy delivered	MWh	758.3	Net GHG reduction	t_{CO2}/yr	230.96
Heating fuel displaced	-	Diesel (#2 oil)	Net GHG emission reduction - 30 yrs	t_{CO2}	6,929

Financial Parameters

Avoided cost of heating energy	$/gal	4.400	Debt ratio	%	0.0%
GHG emission reduction credit	$/$t_{CO2}$	-	Income tax analysis?	yes/no	No
Retail price of electricity	$/kWh	-			
Energy cost escalation rate	%	3.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	30			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	$	-	O&M	$	-
Development	0.0%	$	-	Fuel/Electricity	$	-
Engineering	0.0%	$	-			
Energy equipment	67.5%	$	180,320	**Annual Costs - Total**	$	-
Balance of equipment	15.2%	$	40,500			
Miscellaneous	17.4%	$	46,372	**Annual Savings or Income**		
Initial Costs - Total	100.0%	$	267,192	Heating energy savings/income	$	109,378
Incentives/Grants		$	9,600			
				Annual Savings - Total	$	109,378
Periodic Costs (Credits)						
		$	-			
		$	-			
		$	-			
End of project life -		$	-			

Financial Feasibility

Pre-tax IRR and ROI	%	46.7%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	46.7%			
Simple Payback	yr	2.4	Project equity	$	267,192
Year-to-positive cash flow	yr	2.2			
Net Present Value - NPV	$	1,276,553			
Annual Life Cycle Savings	$	124,255			
Benefit-Cost (B-C) ratio	-	5.78			

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(257,592)	(257,592)	(257,592)
1	112,659	112,659	(144,933)
2	116,039	116,039	(28,894)
3	119,520	119,520	90,626
4	123,106	123,106	213,732
5	126,799	126,799	340,531
6	130,603	130,603	471,134
7	134,521	134,521	605,655
8	138,557	138,557	744,211
9	142,713	142,713	886,925
10	146,995	146,995	1,033,919
11	151,405	151,405	1,185,324
12	155,947	155,947	1,341,270
13	160,625	160,625	1,501,896
14	165,444	165,444	1,667,339
15	170,407	170,407	1,837,747
16	175,519	175,519	2,013,266
17	180,785	180,785	2,194,051
18	186,208	186,208	2,380,259
19	191,795	191,795	2,572,054
20	197,549	197,549	2,769,603
21	203,475	203,475	2,973,078
22	209,579	209,579	3,182,657
23	215,867	215,867	3,398,524
24	222,343	222,343	3,620,866
25	229,013	229,013	3,849,879
26	235,883	235,883	4,085,763
27	242,960	242,960	4,328,722
28	250,249	250,249	4,578,971
29	257,756	257,756	4,836,727
30	265,489	265,489	5,102,216

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RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Solar Air Heating Project

Use GHG analysis sheet? Yes Type of analysis: Standard

Background Information

Project Information
Project name: ADU Site
Project location: Kabul, AFGN

Global Warming Potential of GHG
1 tonne CH_4 = 21 tonnes CO_2 (IPCC 1996)
1 tonne N_2O = 310 tonnes CO_2 (IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	30.0%	8.0%	0.975
Electricity mix	100%	268.5	0.0072	0.0072		8.0%	0.975

Base Case Heating System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	75.0%	0.359

Proposed Case Heating System (Solar Air Heating Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	5.3%	268.5	0.0072	0.0072	100.0%	0.975
Solar	94.7%	0.0	0.0000	0.0000	100.0%	0.000
Heating energy mix	100.0%	14.9	0.0004	0.0004		0.054

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)	Annual GHG emission reduction (t_{CO2})
Heating system	0.359	0.054	758.3	230.96
			Net GHG emission reduction t_{CO2}/yr	230.96

Complete Financial Summary sheet

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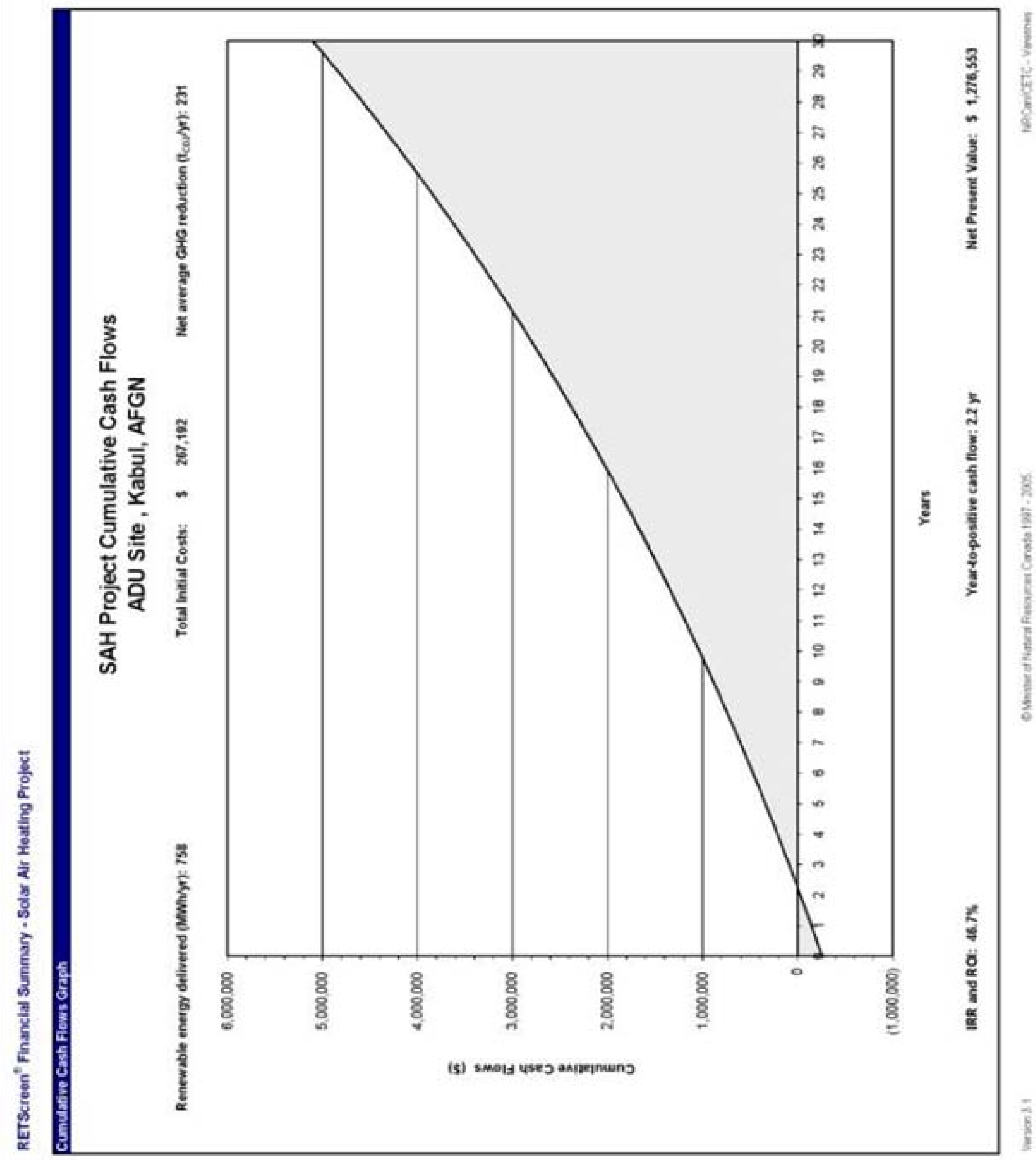
RETScreen® Financial Summary - Solar Air Heating Project
Cumulative Cash Flows Graph
SAH Project Cumulative Cash Flows
ADU Site , Kabul, AFGN
Renewable energy delivered (MWh/yr): 758
Total Initial Costs: $ 267,192
Net average GHG reduction (tCO2/yr): 231
Cumulative Cash Flows ($)
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
(1,000,000)
Years
IRR and ROI: 46.7%
Year-to-positive cash flow: 2.2 yr
Net Present Value: $ 1,276,553

RETScreen® Sensitivity and Risk Analysis - Solar Air Heating Project

Use sensitivity analysis sheet?	Yes	Perform analysis on	After-tax IRR and ROI
Perform risk analysis too?	No	Sensitivity range	20%
Project name	ADU Site	Threshold	15.0 %
Project location	Kabul, AFGN		

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of heating energy ($/gal)				
		3.5200	3.9600	**4.4000**	4.8400	5.2800
		-20%	-10%	0%	10%	20%
607	-20%	31.0%	34.5%	38.0%	41.5%	45.0%
682	-10%	34.5%	38.4%	42.4%	46.3%	50.2%
758	0%	38.0%	42.4%	**46.7%**	51.1%	55.5%
834	10%	41.5%	46.3%	51.1%	55.9%	60.7%
910	20%	45.0%	50.2%	55.5%	60.7%	66.0%

Initial costs ($)		Avoided cost of heating energy ($/gal)				
		3.5200	3.9600	**4.4000**	4.8400	5.2800
		-20%	-10%	0%	10%	20%
213,754	-20%	47.1%	52.7%	58.2%	63.7%	69.2%
240,473	-10%	42.0%	46.9%	51.8%	56.7%	61.6%
267,192	0%	38.0%	42.4%	**46.7%**	51.1%	55.5%
293,911	10%	34.7%	38.7%	42.6%	46.6%	50.5%
320,631	20%	32.0%	35.6%	39.2%	42.8%	46.5%

Annual costs ($)		Avoided cost of heating energy ($/gal)				
		3.5200	3.9600	**4.4000**	4.8400	5.2800
		-20%	-10%	0%	10%	20%
0	-20%	38.0%	42.4%	46.7%	51.1%	55.5%
0	-10%	38.0%	42.4%	46.7%	51.1%	55.5%
0	0%	38.0%	42.4%	**46.7%**	51.1%	55.5%
0	10%	38.0%	42.4%	46.7%	51.1%	55.5%
0	20%	38.0%	42.4%	46.7%	51.1%	55.5%

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RETScreen® Energy Model - Solar Air Heating Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		ADU Site	See Online Manual
Project location		Kabul, AFGN	
Nearest location for weather data		Kabul, AFGN	Complete SR sheet
Annual solar radiation (tilted surface)	MWh/m²	1.21	
Annual average temperature	°C	6.3	
Annual average wind speed	m/s	6.1	

System Characteristics		Estimate	Notes/Range
Heating application type	-	Ventilation air	
Base Case Heating System			
Heating fuel type	-	Diesel (#2 oil) - gal	
Heating system seasonal efficiency	%	75%	0% to 350%
Building			
Building type	-	Commercial	
Indoor temperature	°C	21.0	20.0 to 25.0
Maximum delivered air temperature	°C	40.0	
RSI-value of building wall	m² - °C/W	2.1	0.1 to 10.0
Airflow Requirements			
Design airflow rate	m³/h	76,080	50 to 1,000,000
Operating days per week (weekday)	d/w	5.0	0.0 to 5.0
Operating hours per day (weekday)	h/d	24.0	5.0 to 24.0
Operating days per week (weekend)	d/w	2.0	0.0 to 2.0
Operating hours per day (weekend)	h/d	24.0	5.0 to 24.0
Solar Collector			
Design objective	-	High temperature rise	
Collector colour	-	Black	See Product Database
Solar absorptivity	-	0.94	0.20 to 0.99
Suggested solar collector area	m²	2,113	
Solar collector area	m²	2,113	
Percent shading during season of use	%	0%	0% to 50%
SAH fan flow rate	m³/h/m²	36	
Average air temperature rise	°C	13.6	
Incremental fan power	W/m²	5.0	0.0 to 7.0

Annual Energy Production (9.0 months analysed)		Estimate	Notes/Range
Incremental fan energy	MWh	**69.2**	
Specific yield	kWh/m²	493	
Collector efficiency	%	48%	
Solar availability while operating	%	78%	
Renewable energy collected	MWh	944.1	
Building heat loss recaptured	MWh	98.0	
Renewable energy delivered	MWh	**1,042.1**	
	million Btu	3,555.6	
			Complete Cost Analysis sheet

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F.2 SolarWall™ - Dining Facility

RETScreen® Solar Resource - Solar Air Heating Project

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Kabul, AFGN	See Weather Database
Latitude of project location	°N	34.5	-90.0 to 90.0
Slope of solar collector	°	90.0	0.0 to 90.0
Azimuth of solar collector	°	20.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector (kWh/m²/d)
January	1.00	2.29	-6.3	6.2	3.53
February	1.00	2.83	-4.9	6.1	3.51
March	1.00	3.86	-0.2	6.2	2.94
April	1.00	5.06	5.7	6.4	2.87
May	1.00	6.38	11.1	5.8	2.76
June	0.00	7.40	16.2	5.9	2.70
July	0.00	7.30	18.6	5.7	2.82
August	0.00	6.67	17.4	5.7	3.31
September	1.00	5.66	12.7	6.0	3.94
October	1.00	4.23	6.6	7.0	4.14
November	1.00	2.95	2.0	6.6	3.87
December	1.00	2.17	-3.2	6.1	3.40

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.73	1.08
Solar radiation (tilted surface)	MWh/m²	1.21	0.94
Average temperature	°C	6.3	2.6
Average wind speed	m/s	6.1	6.3

Return to Energy Model sheet

Version 3.1

NRCan/CETC - Varennes

RETScreen® Cost Analysis - Solar Air Heating Project

Type of analysis: Pre-feasibility | Currency: $ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Other - Feasibility study	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Development							
Other - Development	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Engineering							
Other - Engineering	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Energy Equipment							
Solar collector materials	m²	2,113	$ 90	$ 190,170		-	-
Equipment installation	m²	2,113	$ 50	$ 105,650		-	-
Cladding material credit	m²	-2,113	$ -	$ -		-	-
Cladding labour credit	m²	-2,113	$ -	$ -		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Energy Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 295,820	67.1%		
Balance of Equipment							
Fans and ducting materials	m³/h	76,080	$ 1.40	$ 106,512		-	-
Fans and ducting labour	m³/h	76,080	$ 1.00	$ 76,080		-	-
Fan and duct material credit	m³/h	-76,080	$ 1.00	$ (76,080)		-	-
Fan and duct labour credit	m³/h	-76,080	$ 0.50	$ (38,040)		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Balance of Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 68,472	15.5%		
Miscellaneous							
Overhead	%	10%	$ 364,292	$ 36,429		-	-
Training	p-h	0	$ -	$ -		-	-
Contingencies	%	10%	$ 400,721	$ 40,072		-	-
Sub-total :				$ 76,501	17.4%		
Initial Costs - Total				$ 440,793	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	$ -	$ -		-	-
O&M labour	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ -	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 364,292	$ -		-	-
Sub-total :				$ -			
Fuel/Electricity	kWh	69,222	$ -	$ -		-	-
Annual Costs - Total				$ -			

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
				$ -	-	-
				$ -	-	-
				$ -	-	-
End of project life		-		$ -		*Go to GHG Analysis sheet*

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RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Solar Air Heating Project

Use GHG analysis sheet? Yes Type of analysis: Standard

Background Information

Project Information		Global Warming Potential of GHG	
Project name	ADU Site	1 tonne CH_4 = 21 tonnes CO_2	(IPCC 1996)
Project location	Kabul, AFGN	1 tonne N_2O = 310 tonnes CO_2	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	30.0%	8.0%	0.975
Electricity mix	100%	268.5	0.0072	0.0072		8.0%	0.975

Base Case Heating System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	75.0%	0.359

Proposed Case Heating System (Solar Air Heating Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	6.2%	268.5	0.0072	0.0072	100.0%	0.975
Solar	93.8%	0.0	0.0000	0.0000	100.0%	0.000
Heating energy mix	100.0%	17.8	0.0005	0.0005		0.065

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)		Annual GHG emission reduction (t_{CO2})
Heating system	0.359	0.065	1042.1		306.46
			Net GHG emission reduction	t_{CO2}/yr	306.46

Complete Financial Summary sheet

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RETScreen® Financial Summary - Solar Air Heating Project

Annual Energy Balance

Project name		ADU Site	Electricity required	MWh	69.2
Project location		Kabul, AFGN			
Renewable energy delivered	MWh	1,042.1	Net GHG reduction	t_{CO2}/yr	306.46
Heating fuel displaced	-	Diesel (#2 oil)	Net GHG emission reduction - 30 yrs	t_{CO2}	9,194

Financial Parameters

Avoided cost of heating energy	$/gal	4.400	Debt ratio	%	0.0%
GHG emission reduction credit	$/$t_{CO2}$	-	Income tax analysis?	yes/no	No
Retail price of electricity	$/kWh	-			
Energy cost escalation rate	%	3.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	30			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	$	-	O&M	$	-
Development	0.0%	$	-	Fuel/Electricity	$	-
Engineering	0.0%	$	-			
Energy equipment	67.1%	$	295,820	**Annual Costs - Total**	$	-
Balance of equipment	15.5%	$	68,472			
Miscellaneous	17.4%	$	76,501	**Annual Savings or Income**		
Initial Costs - Total	100.0%	$	440,793	Heating energy savings/income	$	150,321
Incentives/Grants		$	9,600			
				Annual Savings - Total	$	150,321
Periodic Costs (Credits)						
		$	-			
		$	-			
		$	-			
End of project life -		$	-			

Financial Feasibility

Pre-tax IRR and ROI	%	38.9%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	38.9%			
Simple Payback	yr	2.9	Project equity	$	440,793
Year-to-positive cash flow	yr	2.7			
Net Present Value - NPV	$	1,677,228			
Annual Life Cycle Savings	$	163,255			
Benefit-Cost (B-C) ratio	-	4.81			

Yearly Cash Flows

Year #	Pre-tax $	After-tax $	Cumulative $
0	(431,193)	(431,193)	(431,193)
1	154,831	154,831	(276,362)
2	159,476	159,476	(116,887)
3	164,260	164,260	47,374
4	169,188	169,188	216,562
5	174,264	174,264	390,825
6	179,491	179,491	570,317
7	184,876	184,876	755,193
8	190,423	190,423	945,615
9	196,135	196,135	1,141,751
10	202,019	202,019	1,343,770
11	208,080	208,080	1,551,850
12	214,322	214,322	1,766,172
13	220,752	220,752	1,986,924
14	227,374	227,374	2,214,298
15	234,196	234,196	2,448,494
16	241,222	241,222	2,689,715
17	248,458	248,458	2,938,174
18	255,912	255,912	3,194,086
19	263,589	263,589	3,457,675
20	271,497	271,497	3,729,172
21	279,642	279,642	4,008,814
22	288,031	288,031	4,296,845
23	296,672	296,672	4,593,517
24	305,572	305,572	4,899,089
25	314,739	314,739	5,213,829
26	324,182	324,182	5,538,010
27	333,907	333,907	5,871,917
28	343,924	343,924	6,215,842
29	354,242	354,242	6,570,084
30	364,869	364,869	6,934,953

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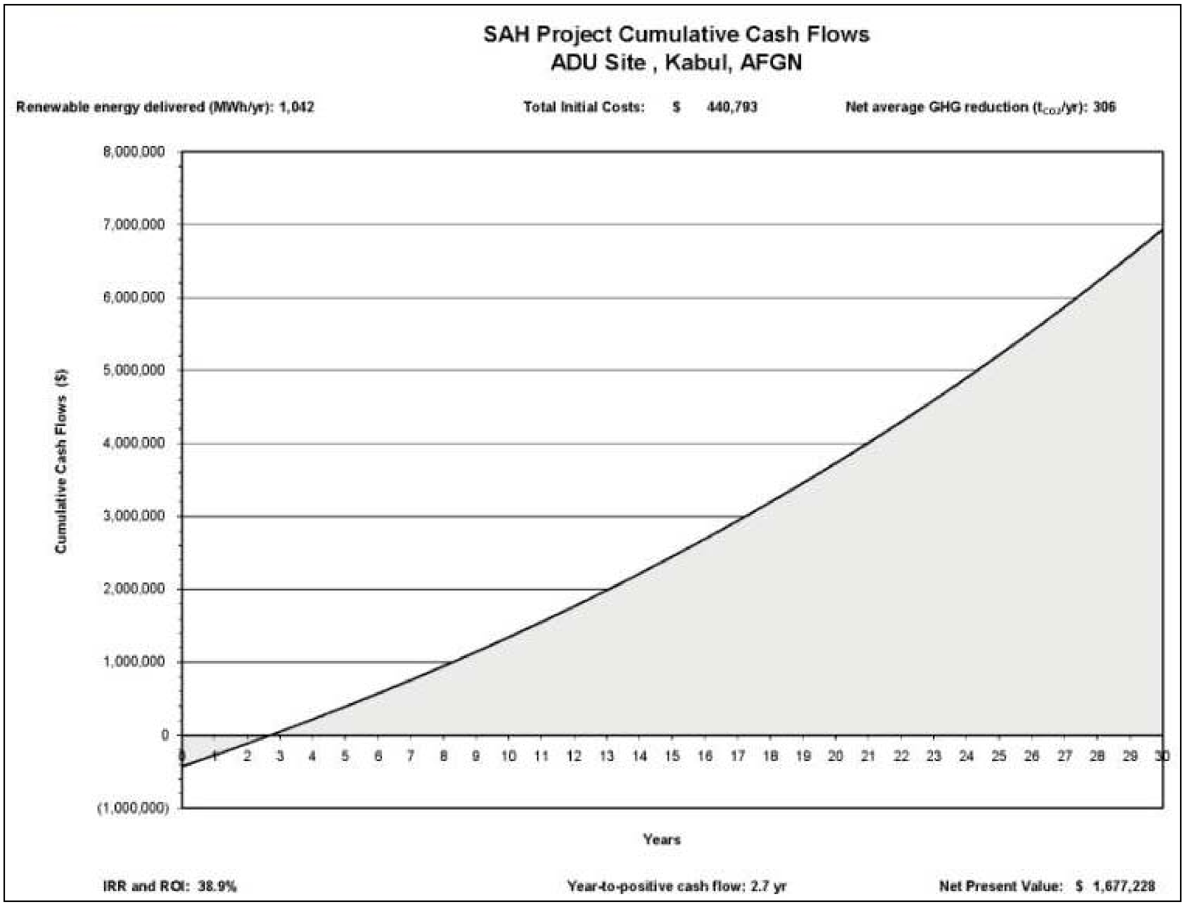
8/20/2010; SolarWall DFAC.xls



RETScreen® Sensitivity and Risk Analysis - Solar Air Heating Project

Use sensitivity analysis sheet?	Yes
Perform risk analysis too?	No
Project name	ADU Site
Project location	Kabul, AFGN

Perform analysis on	After-tax IRR and ROI	
Sensitivity range	20%	
Threshold	15.0	%

Click here to Calculate Sensitivity Analysis

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
834	-20%	25.9%	28.8%	31.7%	34.6%	37.5%
938	-10%	28.8%	32.1%	35.3%	38.5%	41.8%
1,042	0%	31.7%	35.3%	**38.9%**	42.5%	46.1%
1,146	10%	34.6%	38.5%	42.5%	46.4%	50.4%
1,251	20%	37.5%	41.8%	46.1%	50.4%	54.7%

Initial costs ($)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
352,636	-20%	39.1%	43.6%	48.1%	52.6%	57.2%
396,714	-10%	35.0%	39.0%	43.0%	47.0%	51.0%
440,793	0%	31.7%	35.3%	**38.9%**	42.5%	46.1%
484,873	10%	29.0%	32.3%	35.6%	38.8%	42.1%
528,952	20%	26.8%	29.8%	32.8%	35.8%	38.8%

Annual costs ($)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
0	-20%	31.7%	35.3%	38.9%	42.5%	46.1%
0	-10%	31.7%	35.3%	38.9%	42.5%	46.1%
0	0%	31.7%	35.3%	**38.9%**	42.5%	46.1%
0	10%	31.7%	35.3%	38.9%	42.5%	46.1%
0	20%	31.7%	35.3%	38.9%	42.5%	46.1%

F.3 SolarWall™ – Field House

RETScreen® Energy Model - Solar Air Heating Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		ADU Site	See Online Manual
Project location		Kabul, AFGN	
Nearest location for weather data		Kabul, AFGN	Complete SR sheet
Annual solar radiation (tilted surface)	MWh/m²	1.24	
Annual average temperature	°C	6.3	
Annual average wind speed	m/s	6.1	

System Characteristics		Estimate	Notes/Range
Heating application type	-	Ventilation air	
Base Case Heating System			
Heating fuel type	-	Diesel (#2 oil) - gal	
Heating system seasonal efficiency	%	75%	0% to 350%
Building			
Building type	-	Industrial	
Indoor temperature	°C	21.0	20.0 to 25.0
Minimum delivered air temperature	°C	18.5	
Maximum delivered air temperature	°C	40.0	
Building temperature stratification	°C	2.5	0.0 to 15.0
Floor area served by solar collector	m²	3,014	
RSI-value of ceiling	m² - °C/W	3.5	0.1 to 10.0
RSI-value of building wall	m² - °C/W	2.1	0.1 to 10.0
Airflow Requirements			
Design airflow rate	m³/h	55,140	50 to 1,000,000
Operating days per week (weekday)	d/w	5.0	0.0 to 5.0
Operating hours per day (weekday)	h/d	24.0	5.0 to 24.0
Operating days per week (weekend)	d/w	2.0	0.0 to 2.0
Operating hours per day (weekend)	h/d	24.0	5.0 to 24.0
Solar Collector			
Design objective	-	High temperature rise	
Collector colour	-	Black	See Product Database
Solar absorptivity	-	0.94	0.20 to 0.99
Suggested solar collector area	m²	1,532	
Solar collector area	m²	1,532	
Percent shading during season of use	%	0%	0% to 50%
SAH fan flow rate	m³/h/m²	36	
Average solar collector flow rate	m³/h/m²	20.3	
Average air temperature rise	°C	14.1	
Incremental fan power	W/m²	5.0	0.0 to 7.0

Annual Energy Production (9.0 months analysed)		Estimate	Notes/Range
Incremental fan energy	MWh	**50.2**	
Specific yield	kWh/m²	556	
Collector efficiency	%	36%	
Solar availability while operating	%	78%	
Renewable energy collected	MWh	540.1	
Building heat loss recaptured	MWh	70.3	
Destratification savings	MWh	242.0	
Renewable energy delivered	MWh	**852.4**	
	million Btu	2,908.2	
			Complete Cost Analysis sheet

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RETScreen® Solar Resource - Solar Air Heating Project

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Kabul, AFGN	See Weather Database
Latitude of project location	°N	35.5	-90.0 to 90.0
Slope of solar collector	°	90.0	0.0 to 90.0
Azimuth of solar collector	°	20.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector (kWh/m²/d)
January	1.00	2.29	-6.3	6.2	3.66
February	1.00	2.83	-4.9	6.1	3.60
March	1.00	3.86	-0.2	6.2	3.00
April	1.00	5.06	5.7	6.4	2.92
May	1.00	6.38	11.1	5.8	2.81
June	0.00	7.40	16.2	5.9	2.76
July	0.00	7.30	18.6	5.7	2.88
August	0.00	6.67	17.4	5.7	3.37
September	1.00	5.66	12.7	6.0	4.03
October	1.00	4.23	6.6	7.0	4.27
November	1.00	2.95	2.0	6.6	4.04
December	1.00	2.17	-3.2	6.1	3.55

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.73	1.08
Solar radiation (tilted surface)	MWh/m²	1.24	0.97
Average temperature	°C	6.3	2.6
Average wind speed	m/s	6.1	6.3

Return to Energy Model sheet

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RETScreen® Cost Analysis - Solar Air Heating Project

Type of analysis: Pre-feasibility Currency: $ Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Other - Feasibility study	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Development							
Other - Development	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Engineering							
Other - Engineering	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Energy Equipment							
Solar collector materials	m²	1,532	$ 90	$ 137,880		-	-
Equipment installation	m²	1,532	$ 50	$ 76,600		-	-
Cladding material credit	m²	-1,532	$ -	$ -		-	-
Cladding labour credit	m²	-1,532	$ -	$ -		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Energy Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 214,480	67.1%		
Balance of Equipment							
Fans and ducting materials	m³/h	55,140	$ 1.40	$ 77,196		-	-
Fans and ducting labour	m³/h	55,140	$ 1.00	$ 55,140		-	-
Fan and duct material credit	m³/h	-55,140	$ 1.00	$ (55,140)		-	-
Fan and duct labour credit	m³/h	-55,140	$ 0.50	$ (27,570)		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Balance of Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 49,626	15.5%		
Miscellaneous							
Overhead	%	10%	$ 264,106	$ 26,411		-	-
Training	p-h	0	$ -	$ -		-	-
Contingencies	%	10%	$ 290,517	$ 29,052		-	-
Sub-total :				$ 55,462	17.4%		
Initial Costs - Total				$ 319,568	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	$ -	$ -		-	-
O&M labour	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ -	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 264,106	$ -		-	-
Sub-total :				$ -			
Fuel/Electricity	kWh	50,188	$ -	$ -		-	-
Annual Costs - Total				$ -			

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
				$ -	-	-
				$ -	-	-
				$ -	-	-
End of project life		-		$ -		Go to GHG Analysis sheet

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RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Solar Air Heating Project

Use GHG analysis sheet? Yes | Type of analysis: Standard

Background Information

Project Information		Global Warming Potential of GHG		
Project name	ADU Site	1 tonne CH_4 =	21 tonnes CO_2	(IPCC 1996)
Project location	Kabul, AFGN	1 tonne N_2O =	310 tonnes CO_2	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	30.0%	8.0%	0.975
Electricity mix	100%	268.5	0.0072	0.0072		8.0%	0.975

Base Case Heating System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	75.0%	0.359

Proposed Case Heating System (Solar Air Heating Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	5.6%	268.5	0.0072	0.0072	100.0%	0.975
Solar	94.4%	0.0	0.0000	0.0000	100.0%	0.000
Heating energy mix	100.0%	15.8	0.0004	0.0004		0.057

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)	Annual GHG emission reduction (t_{CO2})
Heating system	0.359	0.057	852.4	256.93
			Net GHG emission reduction t_{CO2}/yr	256.93

Complete Financial Summary sheet

Version 3.1

RETScreen® Financial Summary - Solar Air Heating Project

Annual Energy Balance

Project name		ADU Site	Electricity required	MWh	50.2
Project location		Kabul, AFGN			
Renewable energy delivered	MWh	852.4	Net GHG reduction	t_{CO2}/yr	256.93
Heating fuel displaced	-	Diesel (#2 oil)	Net GHG emission reduction - 30 yrs	t_{CO2}	7,708

Financial Parameters

Avoided cost of heating energy	$/gal	4.400	Debt ratio	%	0.0%
GHG emission reduction credit	$/$t_{CO2}$	-	Income tax analysis?	yes/no	No
Retail price of electricity	$/kWh	-			
Energy cost escalation rate	%	3.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	30			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	$	-	O&M	$	-
Development	0.0%	$	-	Fuel/Electricity	$	-
Engineering	0.0%	$	-			
Energy equipment	67.1%	$	214,480	**Annual Costs - Total**	**$**	**-**
Balance of equipment	15.5%	$	49,626			
Miscellaneous	17.4%	$	55,462	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**319,568**	Heating energy savings/income	$	122,953
Incentives/Grants		$	9,600			
				Annual Savings - Total	**$**	**122,953**
Periodic Costs (Credits)						
		$	-			
		$	-			
		$	-			
End of project life -		$	-			

Financial Feasibility

Pre-tax IRR and ROI	%	43.9%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	43.9%			
Simple Payback	yr	2.5	Project equity	$	319,568
Year-to-positive cash flow	yr	2.4			
Net Present Value - NPV	$	1,414,580			
Annual Life Cycle Savings	$	137,690			
Benefit-Cost (B-C) ratio	-	5.43			

Yearly Cash Flows

Year \#	Pre-tax $	After-tax $	Cumulative $
0	(309,968)	(309,968)	(309,968)
1	126,641	126,641	(183,327)
2	130,441	130,441	(52,886)
3	134,354	134,354	81,467
4	138,384	138,384	219,852
5	142,536	142,536	362,388
6	146,812	146,812	509,200
7	151,216	151,216	660,416
8	155,753	155,753	816,169
9	160,425	160,425	976,595
10	165,238	165,238	1,141,833
11	170,195	170,195	1,312,028
12	175,301	175,301	1,487,330
13	180,560	180,560	1,667,890
14	185,977	185,977	1,853,867
15	191,556	191,556	2,045,423
16	197,303	197,303	2,242,726
17	203,222	203,222	2,445,949
18	209,319	209,319	2,655,267
19	215,598	215,598	2,870,866
20	222,066	222,066	3,092,932
21	228,728	228,728	3,321,661
22	235,590	235,590	3,557,251
23	242,658	242,658	3,799,909
24	249,938	249,938	4,049,846
25	257,436	257,436	4,307,282
26	265,159	265,159	4,572,441
27	273,114	273,114	4,845,555
28	281,307	281,307	5,126,862
29	289,746	289,746	5,416,608
30	298,439	298,439	5,715,047

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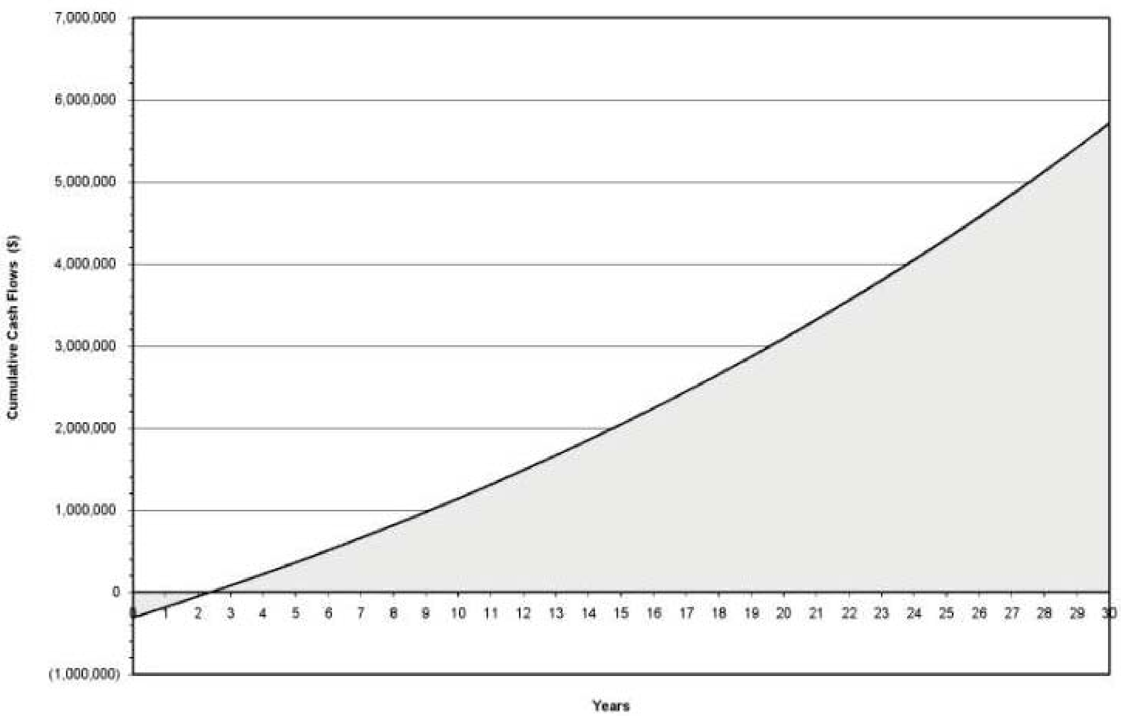
8/20/2010; SolarWall Field house.xls

RETScreen® Financial Summary - Solar Air Heating Project

Cumulative Cash Flows Graph

SAH Project Cumulative Cash Flows
ADU Site , Kabul, AFGN

Renewable energy delivered (MWh/yr): 852 | **Total Initial Costs: $ 319,568** | **Net average GHG reduction (t_{CO_2}/yr): 257**



IRR and ROI: 43.9% | **Year-to-positive cash flow: 2.4 yr** | **Net Present Value: $ 1,414,580**

RETScreen® Sensitivity and Risk Analysis - Solar Air Heating Project

Use sensitivity analysis sheet?	Yes	Perform analysis on	After-tax IRR and ROI
Perform risk analysis too?	No	Sensitivity range	20%
Project name	ADU Site	Threshold	15.0 %
Project location	Kabul, AFGN		

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
682	-20%	29.1%	32.4%	35.7%	38.9%	42.2%
767	-10%	32.4%	36.1%	39.8%	43.4%	47.1%
852	0%	35.7%	39.8%	**43.9%**	47.9%	52.0%
938	10%	38.9%	43.4%	47.9%	52.4%	56.9%
1,023	20%	42.2%	47.1%	52.0%	56.9%	61.8%

Initial costs ($)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
255,655	-20%	44.2%	49.3%	54.5%	59.6%	64.8%
287,611	-10%	39.4%	44.0%	48.6%	53.1%	57.7%
319,568	0%	35.7%	39.8%	**43.9%**	47.9%	52.0%
351,525	10%	32.6%	36.3%	40.0%	43.7%	47.4%
383,482	20%	30.1%	33.5%	36.9%	40.3%	43.6%

Annual costs ($)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
0	-20%	35.7%	39.8%	43.9%	47.9%	52.0%
0	-10%	35.7%	39.8%	43.9%	47.9%	52.0%
0	0%	35.7%	39.8%	**43.9%**	47.9%	52.0%
0	10%	35.7%	39.8%	43.9%	47.9%	52.0%
0	20%	35.7%	39.8%	43.9%	47.9%	52.0%

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F.4 SolarWall™ – Recreational Facility

RETScreen® Energy Model - Solar Air Heating Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		ADU Site	See Online Manual
Project location		Kabul, AFGN	
Nearest location for weather data		Kabul, AFGN	Complete SR sheet
Annual solar radiation (tilted surface)	MWh/m²	1.24	
Annual average temperature	°C	6.3	
Annual average wind speed	m/s	6.1	

System Characteristics		Estimate	Notes/Range
Heating application type	-	Ventilation air	
Base Case Heating System			
Heating fuel type	-	Diesel (#2 oil) - gal	
Heating system seasonal efficiency	%	75%	0% to 350%
Building			
Building type	-	Industrial	
Indoor temperature	°C	21.0	20.0 to 25.0
Minimum delivered air temperature	°C	18.5	
Maximum delivered air temperature	°C	40.0	
Building temperature stratification	°C	2.5	0.0 to 15.0
Floor area served by solar collector	m²	9,067	
RSI-value of ceiling	m² - °C/W	3.5	0.1 to 10.0
RSI-value of building wall	m² - °C/W	2.1	0.1 to 10.0
Airflow Requirements			
Design airflow rate	m³/h	3,470	50 to 1,000,000
Operating days per week (weekday)	d/w	5.0	0.0 to 5.0
Operating hours per day (weekday)	h/d	24.0	5.0 to 24.0
Operating days per week (weekend)	d/w	2.0	0.0 to 2.0
Operating hours per day (weekend)	h/d	24.0	5.0 to 24.0
Solar Collector			
Design objective	-	High temperature rise	
Collector colour	-	Black	See Product Database
Solar absorptivity	-	0.94	0.20 to 0.99
Suggested solar collector area	m²	96	
Solar collector area	m²	96	
Percent shading during season of use	%	0%	0% to 50%
SAH fan flow rate	m³/h/m²	36	
Average solar collector flow rate	m³/h/m²	20.4	
Average air temperature rise	°C	14.0	
Incremental fan power	W/m²	5.0	0.0 to 7.0

Annual Energy Production (9.0 months analysed)		Estimate	Notes/Range
Incremental fan energy	MWh	**3.1**	
Specific yield	kWh/m²	883	
Collector efficiency	%	37%	
Solar availability while operating	%	78%	
Renewable energy collected	MWh	34.0	
Building heat loss recaptured	MWh	4.4	
Destratification savings	MWh	46.4	
Renewable energy delivered	MWh	**84.8**	
	million Btu	289.2	
			Complete Cost Analysis sheet

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RETScreen® Solar Resource - Solar Air Heating Project

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Kabul, AFGN	See Weather Database
Latitude of project location	°N	35.5	-90.0 to 90.0
Slope of solar collector	°	90.0	0.0 to 90.0
Azimuth of solar collector	°	20.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector (kWh/m²/d)
January	1.00	2.29	-6.3	6.2	3.66
February	1.00	2.83	-4.9	6.1	3.60
March	1.00	3.86	-0.2	6.2	3.00
April	1.00	5.06	5.7	6.4	2.92
May	1.00	6.38	11.1	5.8	2.81
June	0.00	7.40	16.2	5.9	2.76
July	0.00	7.30	18.6	5.7	2.88
August	0.00	6.67	17.4	5.7	3.37
September	1.00	5.66	12.7	6.0	4.03
October	1.00	4.23	6.6	7.0	4.27
November	1.00	2.95	2.0	6.6	4.04
December	1.00	2.17	-3.2	6.1	3.55

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.73	1.08
Solar radiation (tilted surface)	MWh/m²	1.24	0.97
Average temperature	°C	6.3	2.6
Average wind speed	m/s	6.1	6.3

Return to Energy Model sheet

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RETScreen® Cost Analysis - Solar Air Heating Project

Type of analysis: Pre-feasibility | Currency: $ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Other - Feasibility study	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Development							
Other - Development	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Engineering							
Other - Engineering	Cost	0	$ -	$ -		-	-
Sub-total :				$ -	0.0%		
Energy Equipment							
Solar collector materials	m²	96	$ 90	$ 8,640		-	-
Equipment installation	m²	96	$ 50	$ 4,800		-	-
Cladding material credit	m²	-96	$ -	$ -		-	-
Cladding labour credit	m²	-96	$ -	$ -		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Energy Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 13,440	67.1%		
Balance of Equipment							
Fans and ducting materials	m³/h	3,470	$ 1.40	$ 4,858		-	-
Fans and ducting labour	m³/h	3,470	$ 1.00	$ 3,470		-	-
Fan and duct material credit	m³/h	-3,470	$ 1.00	$ (3,470)		-	-
Fan and duct labour credit	m³/h	-3,470	$ 0.50	$ (1,735)		-	-
Incremental transportation	project	0	$ -	$ -		-	-
Other - Balance of Equipment	Cost	0	$ -	$ -		-	-
Sub-total :				$ 3,123	15.6%		
Miscellaneous							
Overhead	%	10%	$ 16,563	$ 1,656		-	-
Training	p-h	0	$ -	$ -		-	-
Contingencies	%	10%	$ 18,219	$ 1,822		-	-
Sub-total :				$ 3,478	17.4%		
Initial Costs - Total				$ 20,041	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	$ -	$ -		-	-
O&M labour	project	0	$ -	$ -		-	-
Travel and accommodation	p-trip	0	$ -	$ -		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Contingencies	%	0%	$ 16,563	$ -		-	-
Sub-total :				$ -			
Fuel/Electricity	kWh	3,145	$ -	$ -		-	-
Annual Costs - Total				$ -			

Periodic Costs (Credits)		Period	Unit Cost	Amount	Interval Range	Unit Cost Range
				$ -	-	-
				$ -	-	-
				$ -	-	-
End of project life		-		$ -		*Go to GHG Analysis sheet*

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RETScreen® Greenhouse Gas (GHG) Emission Reduction Analysis - Solar Air Heating Project

Use GHG analysis sheet? Yes | Type of analysis: Standard

Background Information

Project Information		Global Warming Potential of GHG	
Project name	ADU Site	1 tonne CH_4 = 21 tonnes CO_2	(IPCC 1996)
Project location	Kabul, AFGN	1 tonne N_2O = 310 tonnes CO_2	(IPCC 1996)

Base Case Electricity System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	T & D losses (%)	GHG emission factor (t_{CO2}/MWh)
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	30.0%	8.0%	0.975
Electricity mix	100%	268.5	0.0072	0.0072		8.0%	0.975

Base Case Heating System (Baseline)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Diesel (#2 oil)	100.0%	74.1	0.0020	0.0020	75.0%	0.359

Proposed Case Heating System (Solar Air Heating Project)

Fuel type	Fuel mix (%)	CO_2 emission factor (kg/GJ)	CH_4 emission factor (kg/GJ)	N_2O emission factor (kg/GJ)	Fuel conversion efficiency (%)	GHG emission factor (t_{CO2}/MWh)
Heating system						
Electricity	3.6%	268.5	0.0072	0.0072	100.0%	0.975
Solar	96.4%	0.0	0.0000	0.0000	100.0%	0.000
Heating energy mix	100.0%	10.0	0.0003	0.0003		0.036

GHG Emission Reduction Summary

	Base case GHG emission factor (t_{CO2}/MWh)	Proposed case GHG emission factor (t_{CO2}/MWh)	End-use annual energy delivered (MWh)	Annual GHG emission reduction (t_{CO2})
Heating system	0.359	0.036	84.8	27.35
			Net GHG emission reduction t_{CO2}/yr	27.35

Complete Financial Summary sheet

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RETScreen® Financial Summary - Solar Air Heating Project

Annual Energy Balance

Project name		ADU Site	Electricity required	MWh	3.1
Project location		Kabul, AFGN			
Renewable energy delivered	MWh	84.8	Net GHG reduction	t_{CO2}/yr	27.35
Heating fuel displaced	-	Diesel (#2 oil)	Net GHG emission reduction - 30 yrs	t_{CO2}	821

Financial Parameters

Avoided cost of heating energy	$/gal	4.400	Debt ratio	%	0.0%
GHG emission reduction credit	$/$t_{CO2}$	-	Income tax analysis?	yes/no	No
Retail price of electricity	$/kWh	-			
Energy cost escalation rate	%	3.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	30			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	$	-	O&M	$	-
Development	0.0%	$	-	Fuel/Electricity	$	-
Engineering	0.0%	$	-			
Energy equipment	67.1%	$	13,440	**Annual Costs - Total**	**$**	**-**
Balance of equipment	15.6%	$	3,123			
Miscellaneous	17.4%	$	3,478	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**20,041**	Heating energy savings/income	$	12,228
Incentives/Grants		$	9,600			
				Annual Savings - Total	**$**	**12,228**
Periodic Costs (Credits)						
		$	-			
		$	-			
		$	-			
End of project life -		$	-			

Financial Feasibility

Pre-tax IRR and ROI	%	123.6%	Calculate GHG reduction cost?	yes/no	No
After-tax IRR and ROI	%	123.6%			
Simple Payback	yr	0.9	Project equity	$	20,041
Year-to-positive cash flow	yr	0.8			
Net Present Value - NPV	$	161,072			
Annual Life Cycle Savings	$	15,678			
Benefit-Cost (B-C) ratio	-	9.04			

Yearly Cash Flows

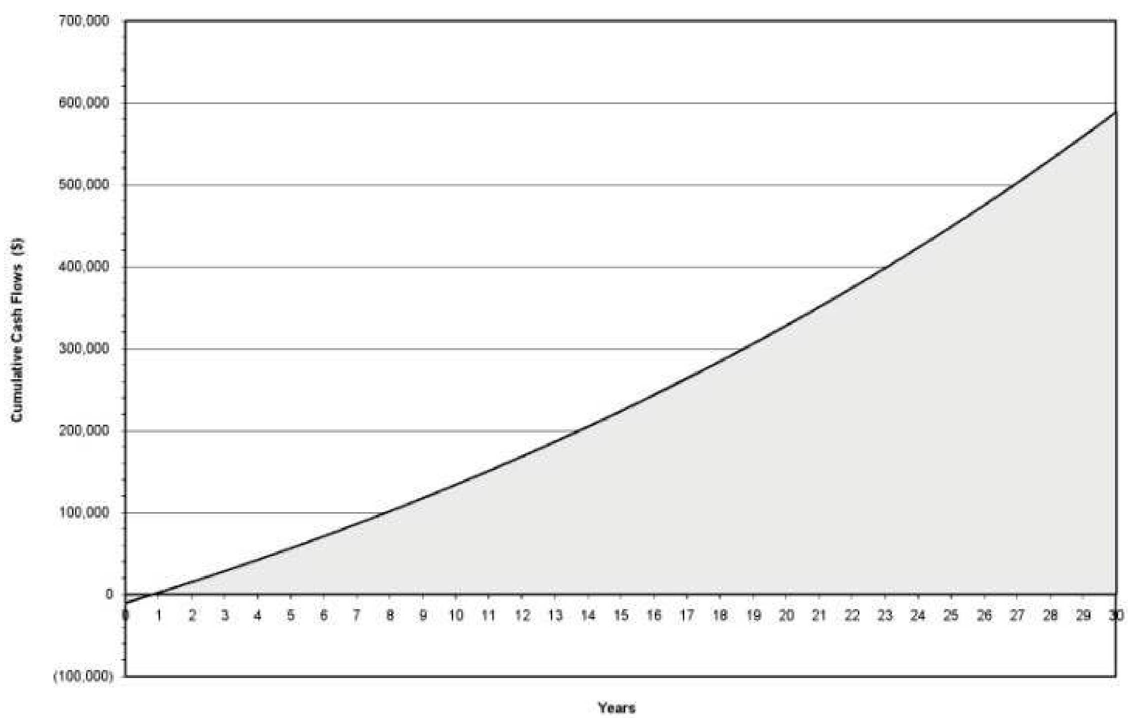
Year #	Pre-tax $	After-tax $	Cumulative $
0	(10,441)	(10,441)	(10,441)
1	12,595	12,595	2,154
2	12,973	12,973	15,127
3	13,362	13,362	28,489
4	13,763	13,763	42,252
5	14,176	14,176	56,427
6	14,601	14,601	71,028
7	15,039	15,039	86,067
8	15,490	15,490	101,558
9	15,955	15,955	117,513
10	16,434	16,434	133,946
11	16,927	16,927	150,873
12	17,434	17,434	168,307
13	17,957	17,957	186,265
14	18,496	18,496	204,761
15	19,051	19,051	223,812
16	19,623	19,623	243,435
17	20,211	20,211	263,646
18	20,818	20,818	284,464
19	21,442	21,442	305,906
20	22,085	22,085	327,991
21	22,748	22,748	350,739
22	23,430	23,430	374,170
23	24,133	24,133	398,303
24	24,857	24,857	423,160
25	25,603	25,603	448,763
26	26,371	26,371	475,134
27	27,162	27,162	502,297
28	27,977	27,977	530,274
29	28,816	28,816	559,090
30	29,681	29,681	588,771

RETScreen® Financial Summary - Solar Air Heating Project

Cumulative Cash Flows Graph

SAH Project Cumulative Cash Flows
ADU Site , Kabul, AFGN

Renewable energy delivered (MWh/yr): 85 | **Total Initial Costs: $ 20,041** | **Net average GHG reduction (t_{CO_2}/yr): 27**



IRR and ROI: 123.6% | **Year-to-positive cash flow: 0.8 yr** | **Net Present Value: $ 161,072**

RETScreen® Sensitivity and Risk Analysis - Solar Air Heating Project

Use sensitivity analysis sheet?	Yes		Perform analysis on	After-tax IRR and ROI
Perform risk analysis too?	No		Sensitivity range	20%
Project name	ADU Site		Threshold	15.0 %
Project location	Kabul, AFGN			

Sensitivity Analysis for After-tax IRR and ROI

RE delivered (MWh)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
68	-20%	80.2%	89.9%	99.5%	109.2%	118.8%
76	-10%	89.9%	100.7%	111.6%	122.4%	133.3%
85	0%	99.5%	111.6%	**123.6%**	135.7%	147.8%
93	10%	109.2%	122.4%	135.7%	149.0%	162.2%
102	20%	118.8%	133.3%	147.8%	162.2%	176.7%

Initial costs ($)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
16,033	-20%	159.6%	179.2%	198.8%	218.4%	237.9%
18,037	-10%	122.4%	137.4%	152.3%	167.2%	182.1%
20,041	0%	99.5%	111.6%	**123.6%**	135.7%	147.8%
22,045	10%	84.0%	94.1%	104.2%	114.3%	124.4%
24,049	20%	72.7%	81.4%	90.2%	98.9%	107.6%

Annual costs ($)		Avoided cost of heating energy ($/gal) 3.5200 -20%	3.9600 -10%	**4.4000** 0%	4.8400 10%	5.2800 20%
0	-20%	99.5%	111.6%	123.6%	135.7%	147.8%
0	-10%	99.5%	111.6%	123.6%	135.7%	147.8%
0	0%	99.5%	111.6%	**123.6%**	135.7%	147.8%
0	10%	99.5%	111.6%	123.6%	135.7%	147.8%
0	20%	99.5%	111.6%	123.6%	135.7%	147.8%

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William T. Brown, John Vavrin, Tarek Abdallah, Jarod Delhotal, Roch Ducey, Franklin H. Holcomb, Nicholas A. Reisweber, Patrick J. Sioson, Chang W. Sohn, William J. Stein, Seth W. Broadfoot, Brian Kamisato, Jerry Christensen, Charles Allen, John Allen, Jeff Hurt, Daniel Patla, Joseph Van Winkle, Ravi Seam, and Suresh Kikkeri

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14. ABSTRACT
This work conducted a site-specific feasibility study to assess the potential use of renewable energy to reduce or replace planned fossil-fueled generators at the Afghanistan National Security University (ANSU) and its supporting facilities located in Qargha, Kabul, Afghanistan. On completion of all phases of construction, ANSU will consume approximately $45M of diesel fuel annually for power production. The Afghanistan Engineer District – North commissioned the US Army Corps of Engineers, Engineering Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) to investigate renewable energy solutions to reduce that annual fuel cost. The team investigated the following technologies: solar photovoltaic (ground-mounted and building-integrated), solar domestic hot water (DHW), wind, geothermal, geo-thermal (ground-source) heat pumps, waste-to energy (including biomass), solar air collector, solar air ventilation, fuel cells, and hydroelectric power. Qualitative facility demand and energy reduction measures were also included. These energy conservation measures can be used as part of the planning and design phases of construction. On review of all potential options, it was determined that seven renewable energy systems were viable, and eight renewable energy technologies were not viable.

15. SUBJECT TERMS
alternative energy, Afghanistan, renewable energy, energy efficient

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